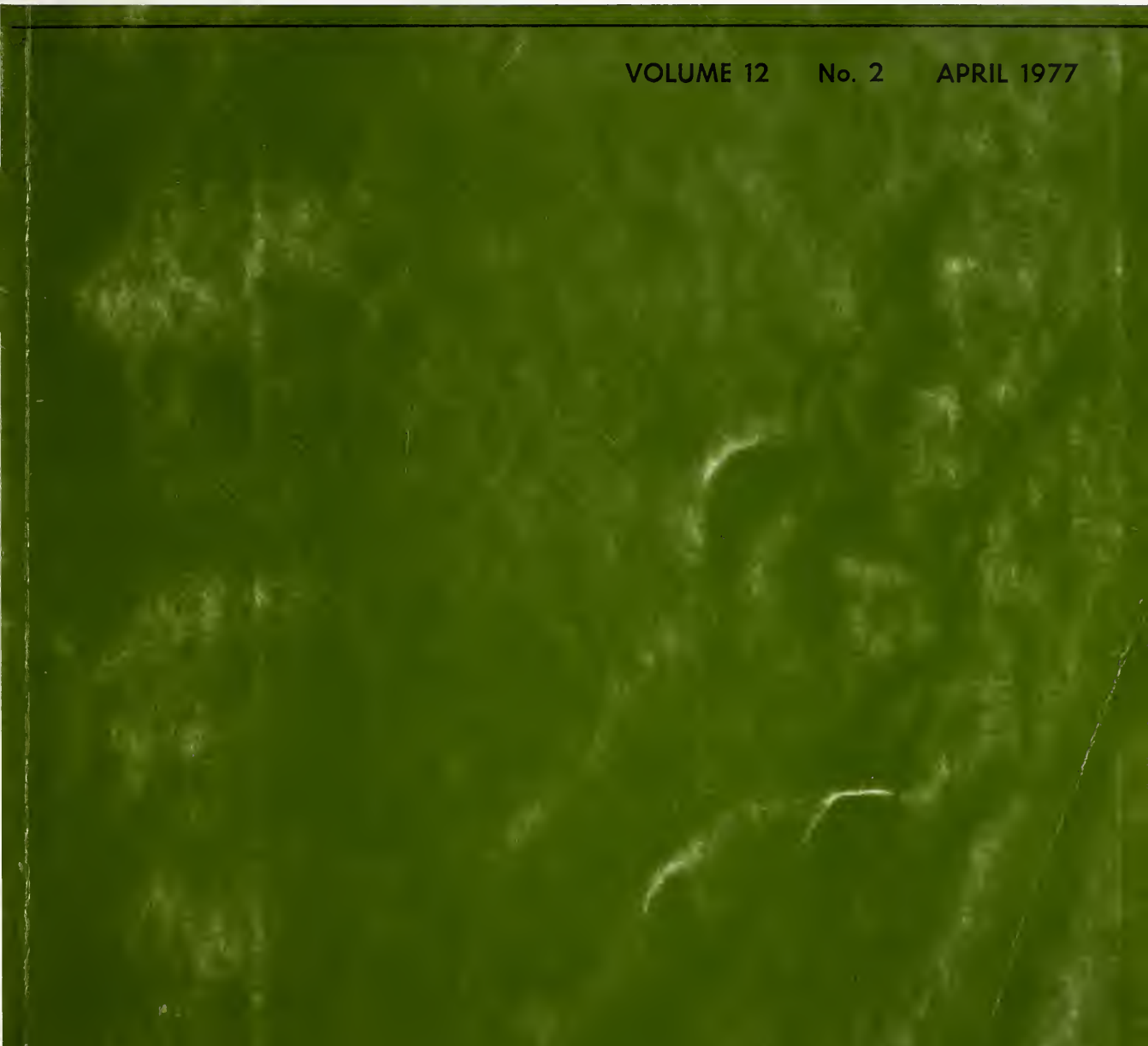
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Hans Justus Thode (1859-1932), pioneer plant collector in the Natal Drakensberg

D. J. B. KILLICK*

ABSTRACT

An account is given of the life of Hans Justus Thode (1859–1932) from the time of his arrival in Cape Town in 1885 or 1886 until his death in Durban in 1932. Thode was the pioneer plant collector of the Natal Drakensberg, but also collected wider afield in all four provinces of the Republic. His contributions to South African botany are assessed.

RESUME

HANS JUSTUS THODE (1859–1932), *PREMIER BOTANISTE RECOLTEUR DANS LES DRAKENSBERG DU NATAL*

La vie de Hans Justus Thode (1859–1932) *est relatée, depuis le moment de son arrivée au Cap en* 1885 (*ou* 1886) *jusqu'à sa mort à Durban en* 1932. *Thode fut le premier à récolter des plantes dans les Drakensberg du Natal, mais ses activités se sont également exercées en d'autres endroits dans les quatre provinces de la République. Un inventaire est dressé de ses contributions à la botanique sud-africaine.*

INTRODUCTION

As a student of the flora of the Natal Drakensberg, it was perhaps inevitable that the author should become interested in the life of Hans Justus Thode (Fig. 1), pioneer plant collector of the Drakensberg and the first to describe its vegetation.

The author was fortunate in obtaining a number of Thode's personal papers, some from Miss M. D. Gunn, former librarian of the Botanical Research Institute, and some from Mr R. G. Strey, Curator of the Natal Herbarium. Otherwise, research on Thode would have been extremely difficult because, from all accounts, he was a retiring and uncommunicative person, who rarely spoke of himself.

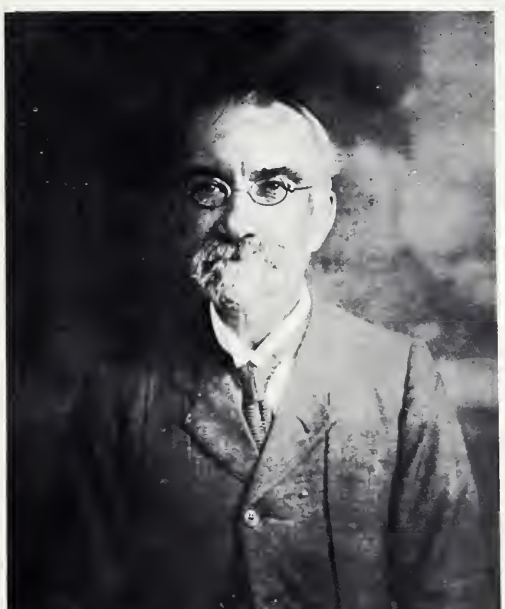


FIG. 1.—Hans Justus Thode. Portrait taken c. 1920.

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

BIRTHPLACE

Thode was born in 1859 probably in Germany. His death notice (Estate No. 18272, Master's Office, Pietermaritzburg), gives his nationality as Swiss, but all evidence points to a German origin. All the people contacted, who knew Thode, accepted him as German without question. Amongst his manuscripts is a poem entitled "All Red" obviously written during or about the time of World War I. The poem is strongly anti-British and would hardly have been written by a Swiss, even a German Swiss. In an article entitled "Journeys in the South African Mountains", Thode refers to the "Riesengebirge at home". The Riesengebirge or Giant Mountains lie between Dresden and Breslau (Wroclaw), in what was formerly Silesia in Germany, but is now in Poland.

According to Mr H. Struck of Draycott, Natal, during World War I Thode gave the authorities to understand that he was Swiss in order to escape possible internment. This may account for the Swiss nationality given on his death notice.

Thode had four sisters and one brother. The one sister Alwine Margarethe Sophie married Carl Alexander Hammer, a storekeeper who, according to Mr H. Zunckel of Bergville, lived at Oliviershoek. In the death notice of this sister, the birthplace is given as Germany. Another sister, Sylvia, married a Mr Mummbrauer of Noodsberg. The two remaining sisters lived in Germany, the one Mrs Käte Putz in Munich and the other Mrs Suzanna Saphir in Leipzig. The brother Felix emigrated to Australia. Mrs Käte Putz's daughter-in-law, Mrs Emmy Putz, claims that she remembers seeing a baptism certificate which indicated that Käte Putz (née Thode) was born in Manchester, England (letter from Dr A. Schreiber, Munich, to Miss M. D. Gunn, 19th August 1966).

To make tracing of Thode's birthplace even more difficult there are suggestions that Thode changed his name on arrival in South Africa. According to Mrs H. Mummbrauer of San Francisco, U.S.A., he was originally called Freylinghausen, while according to Mr Erich Mummbrauer of Bronkhorstspruit, his real name was Von Ettinghausen. Mr Mummbrauer stated that Thode came of military stock but, because of his love of botany, rejected a military carreer and emigrated to South Africa changing his name at the same time. However, no evidence to support these statements has been found.

ARRIVAL AND SOJOURN IN CAPE

In Table 1 Thode's collections from 1886–1906 are listed chronologically. The first collection is dated January 1886–December 1887. From this it would appear that Thode must have arrived in Cape Town in 1885 or early 1886. Why he chose to come to South Africa is not known. While in the south-western Cape he collected intensively and made notes on the Cape flora. He published his observations under the title "Die vier Jahreszeiten am Cap" in a series of articles in Natuurwissenschaftliche Wochenschrift (1892).

TABLE 1.—Thode's collections between 1886–1906

1. First Cape Series (Jan. 86–Dec. 87), 11 fascicles
 (a) First Peninsula Series (Jan. 86–Aug. 87)
 (b) 86 Supplement (Du Toit's Kloof, Mamre, Paarlberg Caledon) Aug. 86
 (c) 87—(Clarkson, etc.) Dec. 87
2. Kaffrarian Series (Dec. 87–Mar. 99)
 (a) First East London Series (Jan. 88–Dec. 89)
 (b) 87–88 nr. Supplement (Gamtoos R., Grahamstown, King William's Town) Dec. 87–Jan. 88
 (c) 99—(Komga, Tembuland, Pondoland) Feb.–Mar. 99
3. First Natal Coastal Series (May–Oct. 90)
4. First Highland Series (Weenen, Klip R. County, O.F.S.) Oct. 90–Mar. 91
5. Second Natal Coastal Series (Apr. 91–July 1906)
 (a) 91 Durban Series (Apr.–Nov. 91)
 (b) 97 Supplement (*Dombeya natalensis*, Avoca) June 97
 (c) 1901–(*Barringtonia*, *Zeuxine*, etc.). June 97
 (d) 1903–(*Disa polygonoides*, Pinetown) Oct. 1903
 (e) 1904–(*Habenaria*, *Mikania*, Lower Umkomaas, etc.) July 1904
6. Second Highland Series (Oliviershoek, ? etc.) Nov. 91–Dec. 92
7. Third Highland Series (O.F.S., Mont-aux-Sources, etc.) Jan. 93–June 94
 (a) Emberton Supplement (*Cynorchis compacta*) Aug. 94
 (b) Transvaal Supplement (*Gerbera jamesonii*) Dec. 1893
8. First Natal Midlands Series (Noodsberg) Oct. 94–Nov. 95
9. Fourth Highland Series (Lesotho, Witzieshoek). Dec. 1895–Jan. 97
 (a) 97 Supplement (*Brachycorythis tenuior*, Emmaus) Jan. 97
10. Second Natal Midland Series (Umsindusi) Feb.–June 97
11. Second Cape Series (July 97–Jan. 99)
 (a) Second Peninsula Series (July 97–Aug. 98)
 (b) 98–99 Supplement (Cedarbergen, Bokkeveld) Oct. 98 Jan. 99
12. Fifth Highland Series (Oliviershoek Pass) Aug. 99–Dec. 1900
13. Sixth Highland Series (Springfontein, Empangweni) June 1902–Jan. 1904
 (a) Springfontein Fasc. (June–Nov. 1902)
 (b) 1904 Supplement (Empangweni, etc.) Jan. 1904
14. Third Cape Series (Aug. 1903)
 (a) Stormberg (Steynsburg) Fascicle
 (b) Karoo (Beaufort West) Fascicle
 (c) Tulbagh Fascicle
 (d) Third Peninsula Series
15. Third Natal Midland Series (Kronsberg, Howick) Jan. 1903–Nov. 1904 (June 1906, Dec.)
 (a) 1905 Supplement (*Schotia brachypetala*, etc.) Aug. 1905
 (b) 1906 Supplement (*Eulophia bicolor*, *Aster erigeroides* etc.) Jan, June 1906
16. Seventh Highland Series (Bushman's Pass Reserve), Jan. 1905

From Table 1 it appears that Thode moved to British Kaffraria in about December 1887 stopping en route at the mission station at Clarkson near Humansdorp. He collected in East London, Grahamstown and King William's Town up to December 1889. It is not known where he was based while in Kaffraria. His observations on the flora of British Kaffraria were published in Engler's Bot. Jahrb. 12: 589–607 (1890).

DRAKENSBERG AND SUBSEQUENT YEARS

In 1890 Thode "first set foot on the blessed soil of fair Natal." Between May and October 1890 he collected along the coast of Natal, but then set off for the "majestic range of the Kathlambe or Drakensberg, which has irresistably attracted and again and again induced me to climb its lofty heights". In the middle of October 1890 he travelled by train to Estcourt, a 10-hour journey, and saw for the first time in the distance the still partly snow-clad Drakensberg. Thode writes: "There it was lying in front of me, the goal of my long cherished dreams and expectations, the rarely visited and little known, almost mythical realm of clouds, once the retreat of robbing Bushmen, whose curious paintings can still be found in many a cave below the cliffs of the river valleys; now a sphere of solitude still unviolated by the devastating activities of man. What an inexpressible incentive to be the first explorer of this *terra incognita,* to open this veiled enchanted country to investigating science and to return with trophies of its interesting flora in the form of many a plant still undescribed." Medley Wood, the Curator of the Natal Herbarium, tried to dissuade Thode from exploring the Drakensberg, pointing out that the mountains were infested with hostile Basothos. This in no way deterred Thode.

He then travelled to the Empangweni Mission (maintained by the Berlin Mission Society), which he had chosen as his "fixed quarters", because of its fairly close proximity to the mountains. His first Drakensberg expedition (29th October 1890) was to Cathkin Peak and Champagne Castle. Unfortunately inclement weather and recalcitrant Bantu bearers prevented him from climbing either of these peaks. Champagne Castle had been successfully climbed two years earlier by the Stocker brothers. Thode described this trip in great detail in a published newspaper article and mentioned some of the more striking plants he encountered. Presumably, his haul of plant specimens was considerable.

A succession of expeditions followed, details of which are given in Table 2.

To enable Thode to pursue his botanical interests, he became a tutor at mission schools and on farms, some situated close to the Drakensberg. He would advertise his services in newspapers. The following is an advertisement found amongst his papers: "Teacher, elderly, ample experience and qualifications desires re-engagement as tutor on farm (Natal or Cape). All standards, Afrikaans, music, etc. Salary £5 p.m. Numerous references." Thode would spend some time in one area and having exhausted it botanically, would take up a post in another area. This was the pattern of his existence to the end.

Thode sent most of his collections to Dr Adolf Engler of the Berlin Herbarium, but apparently did not make much out of his collections financially. Prof. A. W. Bayer (letter of 3rd June 1965) writes that "Thode was convinced that science was to serve mankind and that it was quite wrong for anyone to receive payment or to make money from scientific work". H. Bolus in a letter to A. W. Hill at Kew (26th August 1908) describes Thode as "too peculiar to be hired himself". According to Prof. Bayer, Thode would bring his specimens to Illings Store at Ladysmith and this firm would pack and despatch them to Berlin.

TABLE 2.—Thode's main Drakensberg expeditions

No.	Destination	Date of departure	Place of departure	Remarks
1	Cathkin Peak and Champagne Castle	29/10/1890	Empangweni Mission.....	Did not reach summit
2	Cathedral Peak (Ibotwana)....	5/1/1891	Farm 6 km from Hoffenthal Mission	Did not reach summit
3	Langalibalele Pass (Bushman's River Pass)	27/11/1891	Empangweni Mission.....	Thode's first ascent of summit
4	Mont-aux-Sources.....	1891	Not known	Reached summit
5	Mont-aux-Sources.....	17/2/1893	Farm 32 km from Harrismith.	Reached summit, presumably via Namahi Pass
6	Maluti Mountains.....	1895	Rev. Ross's Mission, Witzieshoek	An unsuccessful expedition because of hostility of Chief Jonathan, son of Molappo, who suspected Thode of being a gold prospector
7	Mont-aux-Sources.....	1896	Not known.....	Reached summit
8	Langalibalele Pass.....	31/12/1904	Lorenz's farm, "Bergvliet"....	Reached summit

By 1894 he had collected to such an extent and seen so much of Natal that he was able to publish an article in Bot. Jahrb. 18, Beibl. 3, 43: 14–45 (1894) describing very accurately the botanical regions of Natal.

In 1930 Markötter published a list of plants collected by Thode at Witzieshoek, Oliviershoek Pass and Koolhoek. These collections cover the period 1891 to 1914, consequently Thode must have spent a considerable time in that area. At Oliviershoek he presumably stayed on occasions with his sister Alwine, whose husband C. A. Hammer had a store there. At Witzieshoek it is known that he often stayed with the Rev. Ross, a missionary, and at "Koolhoek" (Fig. 2) about 21 km south south-east of Memel, he was tutor to the Cronje family in 1907. According to Mr C. J. Cronje, son of Karel Pieter Cronje, Thode also tutored on the farm of Mrs Moorman at Witzieshoek for a time.

However, Thode did not spend all his time during that period in the Witzieshoek–Oliviershoek Pass–Koolhoek area. From Table 1 it will be seen that he visited the Cape Peninsula from July 1897 to August 1898 and the Cedarberg and Bokkeveld from October 1898 to January 1899. He also passed through the eastern Cape (Komga, Tembuland and Pondoland) in February to March 1899 presumably on his way back to Natal. En route he collected on "Prospect Farm" (Komga) belonging to H. G. Flanagan. In August 1903 he visited the Karoo (Steynsburg, Beaufort West, etc.). In 1904–1906 he was tutor on the farm "Kronsberg", Noodsberg, belonging to Mr Herman Mummbrauer. On this farm he met H. Rudatis and actually commenced a combined checklist of birds with Rudatis and Mr G. Mummbrauer.

To gain some idea of Thode's movements between 1908 and 1920 the writer visited the Stellenbosch Herbarium, which contains 6309 of his specimens, and scanned as many of the specimens as possible in the time available, obtaining localities and dates from the labels. Judging from the consecutiveness of some of the dates, it would appear that Thode had several fixed bases during this period. These were apparently: "Sweet Home" (Krantzkop), Sept. 1910–Sept. 1911; "Warrock" (26 km west of Ladysmith), Oct. 1911–March 1913; "Scottspoort" (near Weenen), Oct. 1913–March 1914; Empangweni Mission (near Loskop), Nov. 1914–Jan. 1915; Shakas-



FIG. 2.—Homestead on the farm "Koolhoek" near Memel where Thode was tutor to the Cronje family in 1907.

kraal, April 1914–Sept. 1916 and finally "Yorkshire Wolds" (near Rosetta), Aug.–Nov. 1918. If more specimens had been examined, the periods might have proved to be longer.

Many other localities were noted, some being near the bases already mentioned. It is clear that Thode paid regular visits to southern Natal between 1908 and 1920: there are numerous and sometimes annual collections from "Friedenau", Kenterton, "Moyeni", St Michael's Mission, Oribi Flats, Marburg, Ivunga River, Beach Terminus and Park Rynie. It is likely that Thode visited H. Rudatis and stayed with him on his farm "Umgai". There was certainly contact between Thode and Rudatis, because some of Thode's specimens are marked "ex herb. Rudatis".

In 1911 Thode visited the Transvaal and collected in Pretoria and Heidelberg and in early 1918 he travelled to the Cape and collected at Worcester, Laingsburg, Montagu, Beaufort West and Matjiesfontein. In 1919 he crossed into Pondoland and collected in the vicinity of the Mzamba River. In 1920 he again visited the Transvaal collecting in Pretoria and Rustenburg.

In 1920 Thode was tutor on the farm "Altemooi" belonging to Mr Adrian Daneel. "Altemooi" is situated about 19 km SE of Wakkerstroom and 20 km N of Utrecht. He taught the Daneel children, as well as those of Mr H. Repsold of the farm "Tweekloof" next door. The portait of Thode (Fig. 1) was given to the author by Mrs Elizabeth Rachel Kritzinger (neé Daneel), one of Thode's pupils. Thode stayed at "Altemooi" for two years, then apparently moved to "Tweekloof" for another two years. Many of Thode's specimens (1920–1924) were collected on the farm "Kaffirdrift", another farm belonging to Mr Repsold.

Thode's movements from 1924 to 1931 have been traced by examining the accession book in the National Herbarium, Pretoria, and then getting dates from his specimens in the herbarium (there are 2859 Thode specimens in PRE). In this way Table 3 was compiled. From Table 3 it will be seen that Thode spent a considerable time in the Cape and Transvaal.

In 1925–1926 he was tutor on Mr James Trollip's farm "Glen Makopo", Hobhouse, in the district of Thaba Nchu, Orange Free State.

TABLE 3.—Collecting localities from 1924 to 1931

Year	Month/s	Localities
1924	Feb.–June	Pongola Mountains to Kaffirdrift
	Dec.	Heidelberg–Pretoria–Wonderboom–Warmbaths
1925	Jan.	Burghersdorp, Joubert (Wittebergen)
	Feb.	Joubert (Wittebergen)—probably Joubert's Pass just E. of Lady Grey
	Mar.	"Glen Makopa", Hobhouse
	Aug.	Bloemfontein
	Sept.–Oct.	Graaff-Reinet
	Nov.–Dec.	Uitenhage and Kareedouw
1926	Jan.	Eerste River, Wynberg
	Aug.	Clarkson
	Dec.	Tweekloof, Utrecht
1927	Jan.	Tweekloof, Utrecht
	Sept.	Eshowe
	Nov.–Dec.	Heidelberg
1928	Jan.	Zeerust
	Sept.	Mtunzini
	Oct.	Barberton, Duiwelskantoor
	Nov.	Lydenburg
	Dec.	Potgietersrust
1929	Jan.	Pretoria
	Feb.–Apr.	Aliwal North
	Oct.	Van Rhynsdorp, Wupperthal, Calvinia and Cedarberg
	Nov.	Pakhuis Pass, Piketberg, Franschoek
	Dec.	Ceres
1930	Mar.	Swellendam, George
	Apr.–Aug.	Assegaaibosch, Witte Elsbosch, Klipdrift, Humansdorp
	Sept.–Oct.	Enon
	Dec.	Witbank
1931	Jan.–Mar.	Witbank

FINAL DAYS

According to Table 3 Thode must have made his last collections at Witbank in the Transvaal from December 1930 to March 1931. No records can be traced of specimens collected later than this.

It is likely that he spent his last days in Durban living at 170 Mansfield Road (the address given on his death notice). It is also possible that he spent some of his time in the Natal Herbarium naming his collections. The late Miss Helena M. L. Forbes, former curator of the Natal Herbarium, wrote to Miss Gunn (30th October 1953): "Thode had been in the habit of spending a month or more at the Herbarium naming his specimens every few years. I think he came three times after I came here, once to name up a collection, which he sold to Stellenbosch University".

On 30th May 1932 Dr A. P. D. McLean, who was then stationed at Natal Herbarium, wrote to Dr I. B. Pole Evans, Chief of the Division of Botany, stating that Thode was in Addington Hospital in a critical condition and had been visited by Miss Forbes. According to Miss Forbes, Thode's impecunious state weighed heavily on his mind even when delirious and he was anxious that his collections be sold.

On 1st June 1932 Thode died and was buried in a communal grave with no gravestone at Stella Wood Cemetery, Block N, 1374. Later the grave site was sold and to-day several gravestones occupy the site.

David Strachan & Taylor, accountants of Durban, were asked by the Master of the Supreme Court to handle Thode's estate. Thode died insolvent owing £52. 6s. 6d. It was hoped that the sale of his collection of 2859 numbers would defray this debt. To this end negotiations between Strachan & Taylor and the Division of Botany proceeded protractedly with Dr McLean pressing for the purchase and the Division of Botany expressing little interest because, as Dr E. P. Phillips put it, "The cream of Thode's collections i.e. his high mountain gatherings, had earlier been sold to the University of Stellenbosch".

Eventually, on 3rd May 1934, the Division of Botany offered £36 and this was accepted by the Administrators. There were three or four duplicates of each specimen, so the collection was made up into three sets, one for the Natal Herbarium, one for the National Herbarium, Pretoria, and one for Kew. The specimens were numbered A1, A2, etc. to avoid confusion with his other collections. Unfortunately Thode did not adopt a system of continuous consecutive numbering. This collection was mainly of Transvaal and Cape plants (see Table 3, which was based on this collection). The large wooden trunk in which Thode stored his specimens and other effects, is still in the Natal Herbarium, Durban. Thode's personal effects, beds and odds and ends, were left to his sister Mrs Alwine Hammer of 340 Vause Road, Durban. Some of his books were sold by M. Thompson & Co., auctioneers, for 4/6d.

THODE, THE MAN

Fortunately the author was able to contact four of Thode's past pupils, namely Mr Erich Mummbrauer formerly of the farm "Kronsberg", Noodsberg, in Natal, Mr C. J. Cronje formerly of the farm "Koolhoek" near Memel in the Orange Free State, Mrs E. R. Kritzinger (neé Daneel) formerly of the farm "Altemooi" near Utrecht in Natal and Mrs Lorna Grové (neé Trollip) formerly of the farm "Glen Makopa", Hobhouse, in the Orange Free State.

Discussions with these people revealed a remarkably similar memory of the man. Thode clearly left a lasting impression on them. He was slightly built with a moustache and small beard. He always wore a brown suit buttoned to the top with a wide-brimmed hat or helmet on his head. His plant press was slung high up on his shoulders. He was short-sighted and wore thick spectacles. Thode was an excellent pianist, being passionately fond of Beethoven. He showed little patience with his pupils if they played incorrect notes. Mr Cronje relates how when the family received visitors the children would be asked to play the piano. When a mistake was made, Thode would storm over to the piano and correct the young pianist. The Cronjes asked him to desist from this practice, so on similar occasions when mistakes were made, Thode would walk agitatedly around the room pretending to put all the pictures straight.

He seems to have been an accomplished poet (there are several unpublished poems amongst his papers) and was very fond of the works of Goethe.

He had a good knowledge of the classics as the following incident will show. Mr Heinz Lorenz a former pupil of Thode's at Empangweni Mission School told Mr R. G. Strey of the Natal Herbarium that Thode once taught chemistry and physics at a school in Pietermaritzburg. In the neighbouring classroom the headmaster was giving a lesson in Latin. Thode overheard him incorrectly quoting some Latin verse or prose. When the headmaster a few minutes later left the classroom for some reason or other, Thode quickly nipped into the classroom and corrected the offending quotation on the blackboard. On his return, the headmaster was furious that the quotation had been corrected and promptly sacked Thode.

Mr E. Mummbrauer recalls that after dinner Thode would retire to his room and could be heard walking aroung the room conducting an imaginary orchestra.

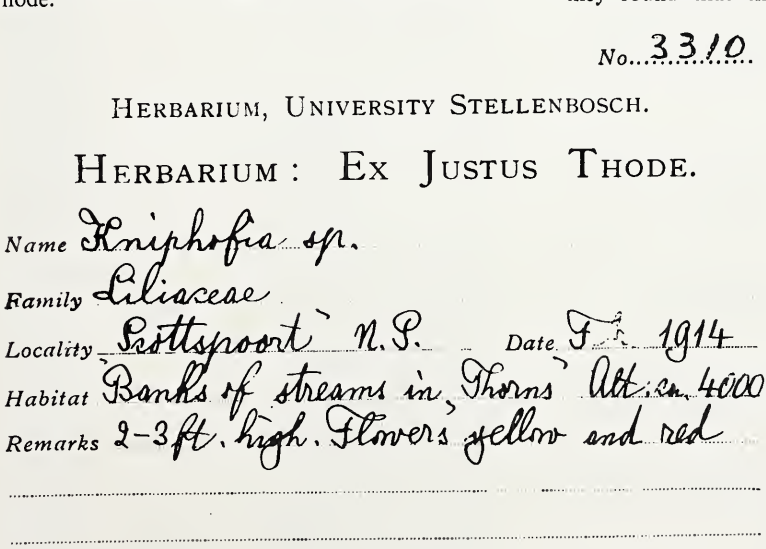
Apparently he never rode on horseback, but used horses for carrying his equipment.

Thode was fond of good food, but disliked Mrs Lorenz's "Mehlklôsse". According to Mr H. Struck of Draycott, Thode would sometimes outstay his welcome on the farm and stay for weeks and weeks. The only way to get rid of him was to put sago pudding regularly on the table.

Mr Struck tells of an incident when Thode went visiting the Zunckels in the Bergville area. To get to the Zunckels, Thode had to cross a river in full spate. He took off his clothes, tied them into a bundle and started to ford the river. Unfortunately the current was strong and he slipped, losing his clothes in the process. Mr Struck describes the amusing sight of Thode running from tree to tree to hide his nakedness and when near the Zunckel homestead being spotted by the children, who ran indoors shouting "There is a naked man outside".

Thode was no respecter of authority. This is amply shown in a letter he wrote to the permit secretary in Durban. He castigated him for his lack of knowledge of geography and ended off with some incredibly rude remarks. He was most indignant when learning from Mr Sydney Barnes, the first conservator of the Drakensberg Game Reserve that he would have to pay 6d per day for each of his party i.e. for himself, Bantu and horse. He wrote: "The Government, or rather the Forestry Department, under whose supervision the Game Reserve is kept, should know best why and for what purpose such an absurd system of (taxation) pillaging travellers has been introduced . . . for our legislators seem too fond of indulging in measures, the wisdom of which is shrouded in mystery quite impenetrable to ordinary common sense".

He was obviously a man with a short temper. Prof. A. W. Bayer (letter to author, 3rd June 1965) tells the story of a collecting trip by ox-wagon made by Thode with Rudolf Schlechter (probably between June and October 1893). Schlechter was apparently rather strict with his Bantu servants and one morning they found that the servants had deserted. After


No. 3310.

HERBARIUM, UNIVERSITY STELLENBOSCH.

HERBARIUM: EX JUSTUS THODE.

Name Kniphofia sp.

Family Liliaceae

Locality Scottsroort N.S. *Date* F. 1914

Habitat Banks of streams in Thorns Alt. ca. 4000'

Remarks 2-3 ft. high. Flowers yellow and red

FIG. 3.—Example of the special label used for Thode's collection in Stellenbosch Herbarium. The handwriting is Thode's.

breakfast, they proceeded to break up camp and to round up and inspan the oxen. Schlechter then picked up the driver's whip and announced to Thode "I will drive; you can voorloop". Thode was so annoyed at this brusque instruction that he went up to the wagon, took his rucksack, turned his back on Schlechter and disappeared into the bush.

CONTRIBUTIONS TO SOUTH AFRICAN BOTANY

Thode's contributions to South African botany lie in the many plant specimens he collected during his 46 years in the country and in his seven publications. As already indicated, he was the first to collect in the Natal Drakensberg, being several years earlier than H. G. Flanagan and H. Bolus (summer 1893–94) and Maurice Evans (1894). Thode was much chagrined when plants like *Erica frigida, E. algida* and *Gladiolus flanaganii* were described from material collected by Flanagan instead of from his material collected three years earlier (letter from Thode to H. Bolus, 5th February 1896).

It is not known how many specimens Thode collected, because he did not consecutively number his specimens. He must have sent thousands of specimens to the Berlin Herbarium; there are 6309 of his specimens in the Stellenbosch Herbarium (Fig. 3), collected between 1886 and 1920, and there are 2859 specimens in the National Herbarium, Pretoria, collected between 1924 and 1931, with duplicate sets in the Natal Herbarium and at Kew. The specimens he collected were of good quality, but often lacked adequate field notes. Oddly enough, Thode did not collect grasses.

Thode is commemorated in the following species: *Alepidea thodei* Dümmer, *Athanasia thodei* H. Bol., *Disa thodei* Schltr., *Erica thodei* Guth. & H. Bol., *Geranium thodei* Schltr., *Holothrix thodei* Rolfe, *Kniphofia thodei* Bak., *Lessertia thodei* L. Bol., *Manulea thodeana* Diels, *Osteospermum thodei* Märk., *Rhodohypoxis thodiana* (Nel) Hilliard & Burtt, *Romulea thodei Schltr.* and *Sebaea thodeana* Gilg.

Thode's papers though few were of a high standard. The following is a list of his publications:

THODE, J.,* 1890. Die Küstenvegetation von Britisch-Kaffrarien und ihr Verhältnis zu den Nachbarfloren. *Bot. Jahrb.* 12: 589–607.

THODE, J., 1892. Die vier Jahreszeiten am Cap. *Naturwissenschaftliche Wochenschrift.* 7,14: 131–133. 15: 144–147. 21: 206–207. 23: 226–228.

THODE, J., 1892. Die botanische Hohenregionen Natals. *Bot. Jahrb.* 18. III Beibl. 43: 14–45.

THODE, J. 1901. The botanical regions of Natal determined by altitude. 16 pp. Durban: Durban Field Naturalists' Society.

THODE, J., 1913. *Leucadendron natalense* Thode & Gilg. *Notizbl. Bot. Gart. Berl.* 5: 290.

THODE, J., 1922. *Bowkeria citrina* Thode. *Kew Bull.* 1922: 31 (1922).

THODE, J., 1924. A new *Pyrenacantha* from Natal. *J. Bot.* 42: 115–116 (1924).

In his first paper, "Die Küstenvegetation von Britisch-Kaffrarien und ihr Verhältnis zu den Nachbarfloren" (1890), Thode compared the coast vegetation of British Kaffraria with that of the south-west Cape and Natal. He showed that although Compositae and Leguminosae were the two dominant families in all three regions, the remaining families differed significantly in their order of importance. Illustrating his broad knowledge and interest in floristics and plant geography, Thode compared the flora of East London with the floras of Ethiopia and India.

* Thode always omitted the initial of his christian name, Hans.

TABLE 4.—Location of some Thode localities mainly in Natal

Farm name and number	Locality	Location	Grid reference
Altemooi 99	—	10 km SNE of Groenvlei	2730 AD
Beach Farm	Marburg	6 km W of Port Shepstone.	3030 CB
—	Beach Terminus	6 km SW of Port Shepstone	3030 CD
Bergveld 5595	—	11 km W of Winterton	2829 CD
—	Bethesda	1,6 km SE of Darnall	2931 AD
—	Bingham's Berg	8 km NE of top of Oliviershoek Pass, O.F.S.	2829 CA
De Rust (probably Rust) 1112	—	8 km NNE of Greytown	2930 BA
—	Empangweni Mission	14 km SE of Loskop	2829 DC
—	Emmaus Mission	18 km NSW of Winterton	2829 CD
—	Empangweni Mission	At Draycott	2829 DC
—	Emyati Mtn. (Mnyati Mtn.)	24 km SE of Vryheid	2730 DD
Friedenau 8635	—	18 km W of Sezela	3030 AD
Georgina 1354	—	16 km SNE of Ladysmith	2829 DB
Glenside 2035	—	16 km SNE of Wartburg	2930 BD
—	Ivunga R. (Vunga R.)	Mouth of river at Uvongo	3030 CD
Kafferdrift (Kaffersdrift)	—	26 km E of Groenvlei	2730 AD
—	Kenterton	5 km NW of Dumisa	3030 AD
—	Koenigsberg	13 km E of Newcastle	2729 DB
Koolhoek 653	—	21 km SSE of Memel, O.F.S.	2729 DC
Leeuwnek 51	—	23 km SE of Vryheid	2731 CC
Little Noodsberg 3167	—	24 km E of Wartburg	2930 BD
Moyeni 9004/9006	—	8 km SSW of Dumisa	3030 AD
—	New Germany	3 km NE of Pinetown	2930 DD
Paulina 1516	—	5 km NW of Van Reenen's Pass, O.F.S.	2829 AD
Reserve 199	—	5 km SE of Volksrust	2729 DD
Scottspoort 2025	—	18 km SSE of Weenen	2830 CC
—	Smiths' Crossing	10 km NW of Ladysmith	2829 BC
—	Stendal Mission	10 km NNE of Weenen	2830 CC
—	St. Michael's Mission	10 km NW of Dumisa	3030 AB
Sweet Home 2175	—	8 km SE of Krantzkop	2930 BB
Twcekloof 100	—	10 km E of Groenvlei	2730 AD
Uitzicht 1926	—	8 km SE of Winterton	2829 DC
—	Umdedelele (Cathkin)	56 km W of Estcourt	2929 AB
Umgai (Umgaye) 8511	—	16 km W of Sezela	3030 BC
Warrock 2159	—	26 km W of Ladysmith	2829 DA
Yorkshire Wolds 8043	—	18 km due E of Rosetta	2929 BD
Zaaihoek 188	—	Not located on maps, but probably SW of Harrismith, O.F.S.	2828 BD

His second paper, "Die vier Jahreszeiten am Cap" (1892) showed a surprising knowledge of the south-west Cape flora after only a short period of residence there. Thode described the four seasons of the Cape and related them to the flora; he commented on the effect of fire on fynbos; he mentioned the exploitation of the flora and urged that conservation measures be adopted.

In 1894 he published "Die botanische Hohenregionen Natals", an accurate picture of altitudinal zonation of vegetation in Natal. This paper stamps Thode as a competent plant geographer. His description of the vegetation of the Natal Drakensberg is the first on record and is extremely accurate as to detail.

In 1901 he published "The botanical regions of Natal determined by altitude". This represents a condensed version of his 1894 paper, translated into English and read before the Durban Field Naturalists' Society on 16th May 1901.

The remaining papers were descriptions of new species.

In conclusion, it may be said that Thode's contributions to South African botany were considerable, especially if it is realized that he was an amateur botanist, attached to no institution, with no library facilities and collecting in remote areas often never collected before. Bolus in writing to A. W. Hill at Kew (26th August 1905) described Thode as "wanting in systematic effort and regularity, and so has not done all he might have done". This is a somewhat harsh judgement, but Bolus does concede that "he has written some valuable papers on the flora of that region".

LOCATION OF CERTAIN THODE COLLECTING LOCALITIES

Taxonomists have frequently found difficulty in locating some of Thode's localities. This is partly due to Thode's frequent use of farm names. To assist taxonomists, the exact location of some of the "problem" localities is given in Table 4.

ACKNOWLEDGEMENTS

Thanks are due to Miss M. D. Gunn for having done some of the spadework in this research and for her continued interest in its progress. Thanks are also due to Miss E. Hagedorn for translating some of the original manuscripts from German to English.

UITTREKSEL

'n Verslag word gegee van die lewe van Hans Justus Thode (1859–1932), *vanaf sy aankoms in Kaapstad in* 1885 *of* 1886 *tot sy dood in Durban in* 1932. *Thode was die baanbreker-plantversamelaar van die Natalse Drakensberge, maar hy het ook verder weg in al vier provinsies van die Republiek plante versamel. 'n Waardasie van sy bydraes tot Suid-Afrikaanse plantkunde word gemaak.*

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Bothalia 12,2:177–179 (1977)

The South African species of *Teucrium* (Lamiaceae)

L. E. CODD*

ABSTRACT

While writing up the three South African species of *Teucrium* for the Flora of Southern Africa it became necessary to replace two well-known names as follows: *T. trifidum* Retz. (1779) (=*T. capense* Thunb., 1800) and *T.* **kraussii** Codd (=*T. riparium* Hochst., 1845, non Rafin., 1838).

RESUME

LES ESPECES SUD-AFRICAINES DE TEUCRIUM *(LAMIACEAE)*

En étudiant les trois espèces sud-africaines de Teucrium *pour inclusion dans la Flore d'Afrique australe, il s'est avéré nécessaire de remplacer comme suit deux noms largement connus:* T.trifidum *Retz.* (1779) (=T.capense *Thunb.*, 1800) *et* T.**kraussii** *Codd* (= T.riparium *Hochst.*, 1845, *non Rafin.*, 1838).

Teucrium is a large genus of perhaps 300 species widely distributed over the temperate and warmer regions of the world, chiefly in the northern hemisphere, but with a few species in Australia, South America and Africa, mainly on the mountains of north-east tropical Africa and into South Africa. Three species are recognized in South Africa and, because the small white flowers are very similar and provide no diagnostic characters, the species are distinguished on vegetative and inflorescence characters. As may be expected, misidentifications have occurred in herbaria, resulting in misconceptions regarding distribution.

Considering the fact that the names commonly applied to these three species have been in use for well over a century, it came as a surprise to find that two name changes were required: (1) *T. trifidum* Retz. (1779) must replace *T. capense* Thunb.; and (2) *T. riparium* Hochst. (1845) is a later homonym of *T. riparium* Rafin. (1838), an American species, and is replaced by a new name, *T. kraussii* Codd.

All three species are used medicinally for stomach disorders and haemorrhoids, as well as for treating snake-bite, while meat suspected of being infested with anthrax is boiled with the plant to render it harmless to eat. Common names such as Aambeibossie and Maagbossie refer to these properties, while Paddaklou and Akkedispoot refer to the variously lobed leaves.

Key to species

Peduncles usually 1-flowered (rarely 3-flowered) and much shorter than the internodes; shrublets 10–30 cm tall; leaves narrowly 3-fid, 0,5–2,5 cm long.....1. *T. africanum*

Peduncles 3–7-flowered, often as long as or longer than the internodes; soft shrubs 30–110 cm tall; leaves 3–5-fid or -lobed, or subentire with a few teeth towards the apex, 2–6 cm long:

Leaves more or less 3–5-fid or -lobed, if subentire then drying greyish.....2. *T. trifidum*

Leaves entire or few-toothed towards the apex, usually drying dark brown.....3. *T. kraussii*

1. **Teucrium africanum** *Thunb.*, Prodr. 2: 95 (1800); Fl. Cap. ed Schult. 445 (1823); Benth., Lab. 669 (1835); in E. Mey., Comm. 243 (1837); in DC., Prodr. 12: 577 (1848); Skan in Fl. Cap. 5,1: 384 (1910). Type: Cape, without locality, *Thunberg* s.n. (UPS, holo.).

Ajuga africana (Thunb.) Pers., Syn. Pl. 2: 109 (1807).

Greyish, bushy shrublet 10–25 (–30) cm tall, branching freely from the base; stems erect to decumbent, simple or sparingly branched, rather densely leafy, greyish glandular-tomentose. *Leaves* 3-fid, 0,8–3 cm long, grey-green; lobes linear to linear-oblong, 0,5–2,5 cm long, 1–3 mm broad, occasionally the median lobe again 3-fid; basal portion of leaf narrow, up to 3 mm broad. *Inflorescence* simple, occupying the upper third of half of the stem; flowers solitary or rarely 2 or 3 per peduncle; peduncles 3–8 mm long, usually distinctly shorter than the internodes.

Found under fairly arid conditions in macchia, karoo, coastal or thorn scrub from Bredasdorp to near Grahamstown and, inland, to Middelburg and Graaff Reinet.

May be separated from the next species, *T. trifidum*, by its smaller stature, rarely exceeding 30 cm tall, and the usually solitary flowers on short peduncles.

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

Bentham, Lab. 670 (1835) and in DC., Prodr. 12: 577 (1848) placed *T. trifidum* Retz. (1799) as being possibly conspecific, while Skan in Fl. Cap, 5,1: 384 (1910) added *T. trifidum* Wendl. (1798) with a question mark. These names are discussed under the next species.

2. **Teucrium trifidum** *Retz.*, Obs. 1: 21 (1779). Type: Cape, without locality, right-hand specimen on sheet in Hb. Retzius (LD, lecto.).

T. trifidum Wendl., Bot. Beobacht. 50 (1798); nom. illegit. Type: not indicated. *T. capense* Thunb., Prodr. 95 (1800); Fl. Cap. ed Schult. 445 (1823); Benth., Lab. 667 (1835); in E. Mey., Comm. 243 (1837); in DC., Prodr. 12: 577 (1848); Skan in Fl. Cap. 5,1: 385 (1910); Wilman, Checklist Griq. W. 231 (1946); Jacot-Guill., Fl. Lesotho 236 (1971); Ross, Fl. Natal 302 (1972). Type: Cape, near "Zeekoerivier" (Humansdorp district), *Thunberg* s.n. (UPS, holo.). *T. africanum* sensu Wilman, l.c. (1946).

Ajuga capensis Pers., Syn. Pl.2: 109 (1807).

An erect soft undershrub 30–110 cm tall, branching freely from the base; stems virgate, branching freely in the upper half or third, woody below, herbaceous above, thinly and shortly greyish tomentose. *Leaves* usually deeply 3-fid or 3–5-partite, rarely almost entire or shortly toothed towards the apex, 2–6 cm long, drying greyish-green to grey-brown, thinly tomentose to almost canescent; lobes linear to lanceolate, 1–3,5 cm long, 3–8 mm broad, often again shortly lobed or toothed; basal portion of leaf 3–8 mm broad. *Inflorescence* a leafy panicle occupying the



FIG. 1.—Type of *Teucrium trifidum* in the Retzius Herbarium, LD (right-hand specimens selected as the lectotype).

upper third of the stem; flowers usually in 3–7-flowered pedunculate cymes, rarely solitary; peduncles 5–20 (25) mm long, usually longer than the internodes.

Common in the central and south-western Transvaal, apparently not extending beyond the Soutpansberg, but extending westwards to the northern Cape Province and just entering Botswana, southwards to northern Natal, central Orange Free State and eastern Cape Province, reaching its south-westerly limit about Humansdorp. Characteristically found in dry woodland where it is often gregarious under thorn trees or in bush groups, particularly on overgrazed or disturbed places.

The leaves of *S. trifidum* vary considerably from lanceolate and almost entire to deeply 3–5-partite. It overlaps with *T. africanum* in the southern Cape from about Grahamstown inland to Queenstown and occasional specimens, from the latter area particularly, may be difficult to place with certainty. *T. africanum* can usually be separated on the basis of the shorter stature, rarely exceeding 30 cm tall, and the usually solitary flowers on short peduncles. In the northern Cape, under semi-arid conditions, *T. trifidum* tends to produce plants shorter than usual with somewhat shorter, but 3-flowered, peduncles. These have often in the past been identified as *T. africanum*, e.g. in Wilman, Checklist Griq. W. 231 (1946), but their affinity lies with *T. trifidum*.

In eastern Cape, about Komga, *T. trifidum* overlaps with *T. kraussii* and here again occasional specimens may need careful study to be sure of their identity. In such cases, specimens of *T. trifidum* with subentire leaves can be recognized by the leaves being somewhat smaller and greyish-green, as against the longer and broader leaves of *T. kraussii*, which tend to dry dark brown.

As mentioned under the previous species, the names *T. trifidum* Retz. (1779) and *T. trifidum* Wendl. (1798) were tentatively included in *T. africanum* by earlier authors. The type of *T. trifidum* Retz. is present in the Retzius Herbarium, Lund, and was kindly sent on loan to me by the Curator, Dr Ove Almborn, whose assistance is gratefully acknowledged. This was examined in relation to the two names published by Thunberg in 1800, *T. africanum* Thunb. and *T. capense* Thunb.

The type sheet, annotated as *Teucrium trifidum* N. by Retzius on the reverse side, has two specimens mounted on it (see Fig. 1). The left-hand specimen corresponds with *T. africanum* Thunb. and the right-hand specimen with *T. capense* Thunb. It is, therefore, necessary to scrutinise the protologue carefully and a copy of the significant parts is given below:

65. TEUCRIUM *trifidum* foliis lanceolatis trifidis, pedunculis axillaribus trifloris.
Habitat ad Cap. B. Spei, unde habui, dono D. BLADH.
Caulis tetragonus, hirtus, ramosus, foliosus.
Folia opposita, lanceolata, majora lobo, minora dente utrinque acuto incisa, ceterum integra, supra scabra, subtus tomentosa; tomento flavescente vix conspicuo.
Pedunculi oppositi, axillares, triflori, longitudine internodiorum.

The epithet *trifidum* would apply more correctly to the left-hand specimen, but the short diagnosis is applicable mainly to the right-hand specimen. The rest of the protologue describes the significant characteristics of the right-hand specimen, eg.: "*Caulis* . . . ramosus . . ."; "*Folia* lanceolata, majora lobo, minora dente utrinque acuto inciso, ceterum integra . . ."; "*Pedunculi* . . . triflori, longitudine internodiorum." In fact no mention is made of the characters exclusive to the left-hand specimen (the deeply trifid leaves and single flowers on short peduncles), while all the characteristics mentioned above apply exclusively to the right-hand specimen.

There is thus nothing in the description to compel one to the view that it is based on a mixture of the two specimens but, assuming that Retzius had both before him, it is considered advisable to make the right-hand specimen the lectotype. This means that *T. capense* Thunb. goes into synonymy.

One may speculate how the specimens were acquired by Bladh, who was a "supercargo" in the Swedish East Indian Company from 1766 to 1784 and sent plants from China, India and South Africa to several Swedish botanists. He is not known to have travelled at all in South Africa, but might have obtained specimens from Thunberg, who had undertaken an expedition together with Masson in 1773–74 to the Sundays River area, where both species are found.

T. trifidum Wendl. is an illegitimate homonym. No specimen is cited but the description suggests that it is conspecific with *T. trifidum* Retz.

3. **Teucrium kraussii** *Codd*, nom. nov. Type: Natal, Umlaas River, *Krauss* 153.

T. riparium Hochst, in Flora 66 (1845); Benth. in DC., Prodr. 12: 576 (1848); Skan in Fl. Cap. 5,1: 385 (1910); Compton, Fl. Swaz. 66 (1966); Ross, Fl. Natal 302 (1972); nom. illegit., non *T. riparium* Rafin. (1838). Type: as above.

An erect soft undershrub 50–110 cm tall, branching from the base; stems simple below, branched in the upper half or third, softly woody below, herbaceous above, finely to fairly densely tomentose, usually with spreading hairs. *Leaves* narrowly lanceolate to oblong–lanceolate or oblanceolate, 2,5–6 cm long, remotely 1—few toothed towards the apex or entire, subglabrous or sparingly hispidulous above, sparingly to fairly densely hispid and minutely gland-dotted below; apex obtuse to acute, base narrowly cuneate. *Inflorescence* a leafy panicle occupying the upper third of the stem, often diffusely branched; flowers in 2–7-flowered pedunculate cymes; peduncles 6–20 mm long, usually longer than the internodes.

Distributed from Swaziland through semi-coastal and midland Natal to King William's Town district in the Cape, in open bush and grassland.

T. kraussii overlaps with *T. trifidum* in the eastern Cape Province and occasional intermediate specimens may be difficult to place with certainty. The main distinguishing characters are discussed under *T. trifidum*.

UITTREKSEL

Tydens die beskrywing van drie Suid-Afrikaanse soorte Teucrium *vir die Flora of Southern Africa, het dit nodig geblyk om twee goedbekende name as volg te vervang*: T. trifidum Retz. (1779) (=T. capense Thunb., 1800) en T. **kraussii** Codd (=T. riparium *Hochst.*, 1845, *non Rafin.*, 1838).

Bothalia 12,2: 181–189 (1977)

A note on the *Stachys aethiopica* Complex

L. E. CODD

ABSTRACT

The *Stachys aethiopica* Complex is examined and a key provided to the species recognized. The combination *S. natalensis* Hochst. var. **galpinii** (Briq.) Codd is effected and two new species, **S. reticulata** Codd and **S. arachnoidea** Codd are described.

RESUME

NOTE SUR LE COMPLEXE DES STACHYS AETHIOPICA

Le complexe des Stachys aethiopica *est examiné et une clé est fournie pour les espèces reconnues. Une nouvelle combinaison est opérée:* S.natalensis *Hochst. var.* **galpinii** *(Briq.) Codd; et deux espèces nouvelles sont décrites:* **S.reticulata** *Codd et* **S.arachnoidea** *Codd.*

Among the South African species of *Stachys* one of the main taxonomic problems concerns the delimitation of species in the *S. aethiopica* Complex. These comprise mainly soft, nondescript, somewhat straggly perennial herbs with small ovate cordate leaves and relatively small, inconspicuous flowers. The complex extends from the south-western extremity of the Cape Province, through the eastern summer-rainfall parts of southern Africa northwards into tropical Africa.

S. aethiopica L., Mant. 1: 82 (1767) was the first to be described and was presumably based on material from the south-western Cape Province. Further species have been distinguished on the basis of differences in tomentum, whether the leaves are petiolate or sessile, on the number of flowers per verticil and, to some extent, on leaf shape.

Our species were reviewed by Skan in Fl. Cap. 5,1: 336–367 (1910), who upheld 19 species in this complex, namely: *S. rehmannii* Skan, *S. malacophylla* Skan, *S. sessilifolia* E. Mey. ex Benth., *S. galpinii* Briq., *S. transvaalensis* Guerke, *S. rudatisii* Skan, *S. parilis* N.E. Br., *S. aethiopica* L., *S. scabrida Skan, S. cooperi* Skan, *S. harveyi* Skan, *S. serrulata* Burch. ex Benth., *S. attenuata* Skan, *S. fruticetorum* Briq., *S. leptoclada* Briq., *S. flexuosa* Skan, *S. cymbalaria* Briq., *S. priorii* Skan, and *S. sublobata* Skan, while the following were treated as "imperfectly known "species: *S. capensis* Presl, *S. graciliflora* Presl, *S. hispidula* Hochst. and *S. natalensis* Hochst. The only species added since then is *H. villosissima* H. M. Forbes from Natal.

Most of these entities represent local variations of restricted extent which may or may not warrant the rank of species. Due to inadequate collecting, many of them are still very poorly known and a good deal more material is required before their status can be assessed.

In the present study the above 24 "species" are reduced to 11, while two additional species are described from the eastern Transvaal and Swaziland. In few cases are there clear-cut differences between species and it is often necessary to rely on a combination of characters.

The picture which emerges is of two widespread and variable species, from which a number of segregate species have arisen or are in the process of developing. The two widespread "parent" species, which can usually be separated on the basis of pubescence, are:

(1) *S. aethiopica* L., with a mainly southern distribution from the south-western Cape to Natal, Lesotho and the Orange Free State, with the lower surfaces of the leaves and calyces thinly tomentulose to hispid or densely glandular;

(2) a more northerly species, to which the name *S. natalensis* Hochst. is applied, extending from Natal to Swaziland, Transvaal and Rhodesia, with the lower surfaces of the leaves and calyces hispid-villous (sometimes only on the nerves) to densely villous (often obscuring the surface), and with scarcely any glands.

The two species meet in Natal, where a gradation in pubescence occurs. In this critical area, however, one can separate them on another character, the number of flowers per verticil. In *S. natalensis* the verticils are 2-flowered throughout its entire range; in *S. aethiopica* the verticils appear to be always 4–6-flowered in Natal, Lesotho and the Orange Free State. In the Cape occasional specimens, some of them rather depauperate, are found with 2 or 3 flowers per verticil, but these do not have villous pubescence and would not be confused with *S. natalensis*. In this way, the two species can be maintained as distinct and some of the confusion of the past concerning the limits of *S. aethiopica* can be clarified.

With regard to the number of flowers per verticil, it must be remembered that there are certain segregate species related to *S. aethiopica* which have 2-flowered verticils (*S. rudatisii, S. cymbalaria* and *S. sublobata*), in the same way that there are species with villous to densely tomentose pubescence related to *S. natalensis* but with 4–6-flowered verticils (*S. malacophylla* and the newly described *S. reticulata*). In other species the number of flowers per verticil is not constant and may very from 2–6 (*S. rehmannii, S. scabrida* and *S. flexuosa*).

From the foregoing it will be realized that the construction of a key that will work satisfactorily for every specimen is not an easy matter. The following key must, therefore, act mainly as a guide. With the increase in knowledge as further material comes in, it is quite likely that our species concepts will be modified.

Key to species in the *S. aethiopica* Complex

Leaves and calyx villous, often densely so, the lower surface of the leaves sparingly hispid-villous to densely tomentose:
- Pubescence stellate.....3. *S. rehmannii*
- Pubescence not stellate:
 - Verticils 2-flowered:
 - Leaves discolorous, sparingly pubescent and greenish-brown above, white tomentose below: bracts leaf-like.....2. *S. arachnoidea*
 - Leaves concolorous; bracts usually differentiated from the leaves:
 - Leaves densely matted-tomentose below obscuring the surface.....6. *S. sessilifolia*
 - Leaves densely to sparingly strigose or hispid below, often mainly on the nerves:
 - Inflorescence compact, 3–6 cm long; corolla purple, the lower lip up to 8 mm long, longer than the tube.....13. *S. flexuosa*
 - Inflorescence fairly compact to lax, (4–) 6–15 cm long; corolla whitish, the lower lip 5–7 mm long, shorter than the tube.....7. *S. natalensis*
 - Verticils normally 4–6-flowered (an occasional 2-flowered verticil may be present):
 - Stem with longish appressed retrorse hairs; leaves often discolorous and reticulate-veined below.....4. *S. reticulata*
 - Stem spreading-pilose to villous or with short retrorse hairs; leaves concolorous:
 - Leaves densely matted-tomentose below, obscuring the surface:
 - Leaves petiolate; uppermost bracts shorter than the calyx.....5. *S. malacophylla*
 - Leaves usually sessile or subsessile; uppermost bracts longer than the calyx....6. *S. sessilifolia*
 - Leaves strigose to hispid below, mainly on the nerves:
 - Leaves drying greenish, truncate to subcordate at the base; inflorescence usually compact.....13. *S. flexuosa*
 - Leaves usually drying brownish, deeply cordate at the base; inflorescense usually lax..8. *S. aethiopica*

Leaves and calyx subglabrous to hispid or glandular-tomentulose, the lower surface of the leaves glabrous to hispid (mainly on the nerves) or glandular-puberulous:
- Verticils 2-flowered:
 - Lower surface of leaf and calyx gland-dotted:
 - Leaves 2–4,5×1,5–2,5 cm, fairly thick-textured; margin finely and regularly crenulate..1. *S. rudatisii*
 - Leaves less than 2 cm long or, if longer, margin rather coarsely toothed:
 - Leaves broadly ovate to suborbicular, shallowly crenate.....11. *S. cymbalaria*
 - Leaves ovate, usually thin-textured, margin rather coarsely toothed.....8. *S. aethiopica*
 - Lower surface of leaves and calyx eglandular or nearly so:
 - Stem glabrous to sparingly retrorse-scabrid or with scattered longish hairs:
 - Leaves drying dark brown, ovate-deltoid; hairs on upper leaf surface, when present, bulbous-based.....10. *S. scabrida*
 - Leaves drying greenish-brown; hairs on upper leaf surface not bulbous-based:
 - Leaf blade broadly ovate to suborbicular, 8–15×6–12 mm; margin shallowly crenate 11. *S. cymbalaria*
 - Leaf blade narrowly triangular, 10–15×4–6 mm; margin deeply crenate.....12. *S. sublobata*
 - Stem variously pubescent but not as above:
 - Stem and rhachis usually hispid-villous, fairly rigid, eglandular (Natal, Swaziland, Transvaal) 7. *S. natalensis*
 - Stem and rhachis shortly retrorse-pubescent to softly pilose often glandular (western Cape) 8. *S. aethiopica*
- Verticils 4–6-flowered (an occasional 2-flowered verticil may be present):
 - Stem subglabrous to sparingly retrorse-scabrid or with scattered multicellular retrorse hairs; hairs on upper leaf surface, when present, bulbous-based.....10. *S. scabrida*
 - Stem variously pubescent but not as above:
 - Inflorescence of 1–4 (rarely more) verticils, often subcapitate to somewhat spaced below; calyx, rhachis and leaves eglandular; stem shortly and softly retrorse-pubescent.....9. *S. graciliflora*
 - Inflorescence usually slender of few to several spaced verticils (rarely subcapitate); glandular hairs or gland-dots often present on calyx, rhachis and lower surface of leaves; stem variously pubescent.....8. *S. aethiopica*

1. **Stachys rudatisii** *Skan* in Fl. Cap. 5, 1: 347 (1910); Ross, Fl. Natal 304 (1972). Type: Natal, Dumisa, *Rudatis* 405 (K, holo.; NH!, PRE!).

Stems glandular hispidulous with retrorse multicellular hairs and copious short glandular hairs. *Leaves* petiolate, rather large; blade ovate, (2–) 3–4,5×(1,5–)2–2,5 cm, the lower surface densely glandular-hispidulous; margin finely crenulate. *Bracts* leaf-like to somewhat differentiated. *Verticils* 2-flowered. *Calyx* glandular hispid.

A little-known species from southern Natal where it apparently grows in damp grassy places among rocks and in shady thickets.

Natal.—3029 (Kokstad): Ngeli Mt. (-DA), *Hilliard & Burtt 3488*. 3030 (Port Shepstone): Dumisa (-AD), *Rudatis 405*.

S. aethiopica (p. 186) often has densely glandular stems and leaves but the leaves are usually smaller, broadly ovate and rather coarsely toothed, while the verticils are normally 4–6-flowered, not 2-flowered as in *S. rudatisii*. In the type, *Rudatis* 405, the bracts are large and leaf-like, while in *Hilliard & Burtt* 3488 the bracts are reduced, making it somewhat intermediate with *S. aethiopica*. A specimen from the Hogsback, *Rattray* sub BOL 14275, may belong here, but the leaves are broadly ovate and subsessile. If the specimen were included here, the known area of the spesies would be extended considerably but more material, especially from the type area, is required before the limits of the species can be assessed.

2. **Stachys arachnoidea** *Codd*, sp. nov., a *S. natalensis* Hochst. foliis discoloribus, subtus dense albo-tomentosus et minute flavo-punctatis differt.

Herba, perennis, aromaticus; caules procumbens vel subscandens, ramosus, usque ad 1 m longus, quadrangularis, sulcatus, dense et molliter albo-tomentosus. *Folia* subsessilia vel breviter petiolata; petiolus usque ad 1 cm longus; lamina late ovato-deltoidea vel subrotunda, 1,8–4 cm longa, 1,5–3 cm lata, chartacea, supra olivacea tenuiter pubescens, subtus dense albo-arachnoidea et minute flavo-punctata, apice obtuso vel rotundato, basi cordata, margine crenulata. *Inflorescentia* laxa, 5–15 cm longa; bracteae foliiformes versus apicem leviter parviores; verticillastri 2-floribus; pedicelli 1,5 mm longi. *Calyx* tubuloso-campanulatus, 8–9 mm longus, dense et molliter albo-tomentosus et minute punctatus; dentes deltoideo-lanceolati, 3–4 mm longi. *Corolla* alba, malvino-maculata, subtiliter glanduloso-pubescens; tubus 8–9 mm longus, 2 mm diam.; labium posticum ascendens, concavum, 3–4 mm longum, 3 mm latum, apicem rotundato; labium anticum horizontale, 8–9 mm longum, lobo medio obcordato, 4 mm longo, lobis lateralibus rotundatis, 1,5 mm longis. *Stamina* 4, 2–3 mm fauce exserta. *Stylus* bifidus, 2 mm exsertus.

Type.—Swaziland, near Mbabane, *Compton* 25890 (PRE, holo.!).

Perennial aromatic herb; stems procumbent to subscandent, branched, up to 1 m long, 4-angled, grooved, densely and softly white tomentose. *Leaves* subsessile to shortly petiolate; petiole up to 1 cm long; blade broadly ovate-deltoid to subrotund, 1,8–4 cm long, 1,5–3 cm broad, chartaceous, greenish and thinly pubescent above, the lower surface with a dense white web-like tomentum and freely supplied with minute yellowish pustule-like gland-dots; apex obtuse to rounded, base cordate; margin crenulate. *Inflorescence* lax, 5–15 cm long; bracts leaf-like, slightly smaller towards the apex; verticils 2-flowered; pedicels 1,5 mm long. *Calyx* tubular-campanulate, 8–9 mm long, densely and softly white tomentose and minutely gland-dotted; teeth deltoid-lanceolate, 3–4 mm long. *Corolla* white spotted with mauve, finely glandular-pubescent; tube 8–9 mm long, 2 mm in diameter; upper lip ascending, concave 3–4 mm long, 3 mm broad, apex rounded; lower lip horizontal, 8–9 mm long, median lobe obcordate, 4 mm long, lateral lobes rounded, 1,5 mm long. *Stamens* 4, exserted by 2–3 mm. *Style* bifid, exserted by 2 mm. Fig. 1.

Found in forest margins and on grassy slopes in the mountains of eastern Transvaal and northern Swaziland at altitudes of 1 300–2 000 m.

Transvaal.—2329 (Pietersburg): near Haenertsburg (–DD), *Codd 9453.* 2330 (Tzaneen): Westfalia Estate (–CA), *Scheepers 729;* Woodbush Forest (–CC), *Mogg 20300;* Agatha (CC), *McCallum s.n.* 2430 (Pilgrims Rest): Mariepskop (–DB), *Van der Schijff 4401; 5139.* 2530 (Lydenburg): 18 km W. of Sabie (–BA), *Codd 9858.*

Swaziland.—2531 (Komatipoort): Havelock area (–CC), *Miller 5858; Compton 30650.* 2631 (Mbabane); Forbes Reef (–AA), *Compton 30492;* near Mbabane (–AC), *Bolus 12242* BOL); *Compton 25890; 26481.*

Although first collected as early as 1905 by Bolus near Mbabane in Swaziland, this species has been confused with *S. transvaalensis* (now included in *S. natalensis*, p. 185) and *S. rudatisii*. It was listed under both these names by Compton, Fl. Swaz. 66 (1966), but can be distinguished by the rounder, discolorous leaves with white cobwebby tomentum and minute yellow gland-dots on the lower surfaces. It shows no close relationship to any other species and is probably the most clear-cut member of the *S. aethiopia* complex.



Fig. 1.—*Stachys arachnoidea*, near Mbabane, Swaziland (*Compton* 25890 in PRE, holotype), × ½.

3. **Stachys rehmannii** *Skan* in Fl. Cap. 5,1: 345 (1910). Type: Transvaal, Houtbosch, *Rehmann* 6178 (K, holo.!).

Stem sparsely to densely stellate-hispid. *Leaves* petiolate, blade ovate-deltoid to subrotund, 1,6–2,2×1,5–2 cm, densely grey stellate-hispid on both surfaces. *Bracts* differentiated from the leaves towards the apex. *Verticils* usually 2-flowered but sometimes 4–6-flowered. *Calyx* densely and shortly stellate-villous.

Found among rocks in mountain grassland at altitudes of 1 300–2 200 m in the northern and north-eastern Transvaal.

Transvaal.—2328 (Baltimore): Blouberg (–BB), *Codd & Dyer 9022; Van der Schijff 5399; Strey & Schlieben 8515.* 2329 (Pietersburg): Houtboschberg (–DD), *Schlechter 4454.* 2330 (Tzaneen): 2 km E. of Steilkop, New Agatha (–CC), *Muller & Scheepers 73.* 2430 (Pilgrims Rest): The Downs (–DD), *Rogers 22027.*

Readily distinguished from all other members of the *S. aethiopica* complex by the presence of dense stellate pubescence on all parts of the plant.

4. **Stachys reticulata** *Codd*, sp. nov., a *S. aethiopica* L. foliis discoloribus, subtus reticulatis dense tomentosis, dentibus calyce patentibus differt.

Herba, perennis, aromaticus; caules decumbens vel procumbens, ramosus, usque ad 60 cm longus, inflorescentiis adscendentibus, dense retrorso-pilosus. *Folia* petiolata; petiolus 5–12 mm longus; lamina ovato-deltoidea, late ovata vel subreniformis, 1–2,5×0,8–2,2 cm, subcoriacea, plerumque discolor,

supra hispida, subtus reticulata, dense glandulosotomentosa, basi late cordata, apice obtuso vel subacuto, margine crenulata. *Inflorescentia* laxa, 4–8 cm longa, interdum subcapitata; bracteae reductae, superis calyce breviores; verticillastri 4–6 floribus; pedicelli 1 mm longi. *Calyx* tubulosocampanulatus, 7–8 mm longus, dense glandulosohispidus; dentes lineari-lanceolati, acuminati, 2,5–3 mm longi, patentes. *Corolla* alba vel lilacina, subtiliter glanduloso-pubescens; tubus 8–9 mm longus, 2 mm diam.; labium posticum horizontale, oblongum, 4–5 mm longum, concavum; labium posticum deflexum, 6–7 mm longum, lobo medio subrotundo, 4 mm longo, lobis lateralibus 2 mm longis. *Stamina* 4, 4 mm fauce exserta; filamenta puberula. *Stylus* bifidus, 4 mm exsertus.

Type.—Transvaal, Mariepskop, *Werdermann & Oberdieck* 1868 (PRE, holo.!).

Perennial aromatic herb; stems decumbent to procumbent, branched, up to 60 cm long with the inflorescences ascending, 4-angled, fairly densely retrorse pilose. *Leaves* petiolate; petiole 5–12 mm long; blade ovate-deltoid to broadly ovate or subreniform, 1–2,5×0,8–2,2 cm, fairly firm textured, usually discolorous, upper surface hispid, lower surface reticulate-veined, densely glandular-tomentose; base broadly cordate, apex obtuse to subacute; margin crenulate. *Inflorescence* lax, 4–8 cm long, occasionally subcapitate; bracts reduced, the upper ones shorter than the calyx; verticils 4–6-flowered; pedicels 1 mm long. *Calyx* tubular-campanulate, 7–8 mm long, densely glandular-hispid; teeth linear-lanceolate, acuminate, 2,5–3 mm long, spreading. *Corolla* white to pale mauve, finely glandular-pubescent; tube 8–9 mm long, 2 mm in diameter; upper lip horizontal, oblong, 4–5 mm long, concave; lower lip deflexed, 6–7 mm long median lobe subrotund, 4 mm long, lateral lobes 2 mm long. *Stamens* 4, exserted by 4 mm; filaments puberulous. *Style* bifid, exserted by 4 mm. Fig. 2.

Found among rocks in exposed situations in mountain grassland in the Pilgrims Rest District of the eastern Transvaal at altitudes of 1 500 to 2 200 m.

Transvaal.—2430 (Pilgrims Rest): Mariepskop (–DB), *Meeuse 9963; Killick & Strey 2391; Werdermann & Oberdieck 1868; Bos 1028; Van der Schijff 4456; 4823;* near Pilgrims Rest, Black Hill, *Galpin 14342;* W. of Pilgrims Rest, *Meeuse 10047;* God's Window, 10 km N. of Pilgrims Rest, *Davidson & Mogg* 33093.

Although confused in the past with *S. aethiopica, S. reticulata* may be distinguished by the usually discolorous leaves, reticulate and densely tomentose below, and by the spreading calyx teeth, The tomentum on the stems is also characteristic being fairly densely appressed pilose. The stem pubescence of *S. aethipica* varies from retrorse to antrorse or spreading, but is usually short and hispid.

From *S. natalensis* it differs in the 4–6-flowered verticils, the reticulate venation on the undersides of the leaves and in the spreading calyx teeth, while from *S. rehmannii* it can readily be separated by the simple, not stellate, pubescence.

It was first collected on the exposed summits of hills near Pilgrims Rest by Galpin in 1937 and appears to be restricted to the mountains of the Pilgrims Rest District, where it usually grows among rocks of the Black Reef quartzite formation.

5. **Stachys malacophylla** *Skan* in Kew Bull. 1909: 421 (1909); Fl. Cap. 5,1: 345 (1910). Lectotype: Cape, Queenstown, *Galpin* 1955 (K, lecto.; PRE!).



Fig. 2.—*Stachys reticulata*, Mariepskop, Transvaal (*Werdermann & Oberdieck* 1868 in PRE, holotype), × ½.

Stem fairly densely spreading-pilose. *Leaves* petiolate, blade broadly ovate, 1,4–3×1–2,2 cm, densely appressed pilose above, matted velvety pilose below. *Bracts* differentiated from the leaves. *Verticils* usually 4–6-flowered but sometimes 2- or 3-flowered. *Calyx* densely hispid-villous.

A little-known species from mountains in the eastern Cape Province.

Cape.—3126 (Queenstown); near Queenstown (–DD), *Galpin 1955; 5891.* 3227 (Stutterheim): King William's Town (–CD), *Sim 19590.*

Closely related to *S. sessilifolia* from which it is separated by the petiolate leaves and usually 4–6-flowered verticils, while the tomentum on the stems and leaves is less densely woolly. Both species are very poorly known and further collecting is required in order to establish how reliable these distinctions are. See also notes under *S. reticulata* from the eastern Transvaal.

6. **Stachys sessilifolia** *E. Mey. ex Benth.* in E. Mey., Comm. 239 (1837); Drège, Zwei Doc. 151 (1843); Benth. in DC., Prodr. 12: 476 (1848); Skan in Fl. Cap. 5,1: 345 (1910) Type: Cape, between Umzimvubu and Umsikaba Rivers, *Drège* 4752 (K, holo.!).

S. bachmannii Guerke in Bot. Jahrb. 26: 75 (1898). Type: Cape, Pondoland, *Bachmann* 1169.

Stem densely and softly villous. *Leaves* shortly petiolate below, sessile above; blade ovate to ovate-deltoid or narrowly ovate, 1–2,2×0,7–1,1 cm,

densely appressed villous above, densely matted-villous below. *Bracts* leaf-like, becoming smaller towards the apex. *Verticils* usually 2-flowered (but up to 6-flowered according to Fl. Cap.). *Calyx* densely shaggy-villous.

Found in dense grassland in the eastern Cape Province.

CAPE.—3029 (Kokstad): Mt. Currie (–AD), *Tyson 1331*. 3129 (Port St Johns): between Umzimvubu and Umsikaba Rivers (–BD?), *Drège 4752* (*K*).

A little-known species closely related to *S. natalensis* and which may be only an extreme form of that species, distinguished by the densely matted-villous lower surface of the leaves. Further material is required in order to determine how meaningful this distinction is.

A specimen from northern Natal, Grid 2730 (Vryheid): near Luneburg (–BC), *Galpin* 9870, has this type of tomentum and 2-flowered verticils but differs in having petioles up to 7 mm long. It is tentatively included in *S. sessilifolia* until more material is forthcoming in order to assess the importance of subsessile versus petiolate leaves. It may be noted that this character varies a good deal in the material included in *S. natalensis* below.

The type of *S. bachmannii* has not been seen; the species was included in *S. sessilifolia* by Skan and, judging by its description, this decision appears to be correct.

7. **Stachys natalensis** *Hochst.* in Flora 28:65 (1845). Type: Natal, Table Mt., *Krauss* 1139.

Stems variously pubescent from densely to sparingly villous or shortly scabrid to softly pubescent. *Leaves* subsessile or petiolate; blade ovate to ovate-deltoid, variable in size, 1–4×0,6–2,4 cm shortly and sparingly appressed pubescent to densely strigose above, less dense, more spreading and mainly on the nerves below often with some glandular hairs but not conspicuously glandular. *Bracts* differentiated towards the apex. *Verticils* 2-flowered. *Calyx* densely villous to densely and shortly pubescent, usually without glands.

A widespread and variable species found in grass on stony hillsides, in semi-shady kloofs and wooded places in the mountains of northern central and eastern Transvaal, Swaziland, northern and coastal Natal as far south as Durban, with an occasional record from the eastern Cape. Also recorded from Rhodesia.

No material of the type, *Krauss* 1139 from Table Mt., near Pietermaritzburg, has been traced, but the description is considered adequate to identify it with the present concept, though Skan, l.c., lists it as an "imperfectly known species." The specimen *Schlechter* 2894 from near Verulam, Natal, may be regarded as representative and, if no material of the type can be found, would be a suitable specimen to select as a lectotype.

Two varieties, based mainly on the degree of pubescence, are recognized.

Key to varieties

Pubescence on stem, leaves and calyx sparingly villous to shortly scabrid or tomentose..... (a) var. *natalensis*

Pubescence on stem, leaves and calyx densely villous..... (b) var. *galpinii*

(a) var. **natalensis.**

Stachys natalensis Hochst. in Flora 65 (1845); Skan in Fl. Cap. 5,1: 367 (1910); Ross, Fl. Natal 303 (1972). Type: Natal, Table Mt., *Krauss* 1139. *S. transvaalensis* Guerke in Bot. Jahrb. 28: 316 (1901); Skan, l.c. 346 (1910). Type: Transvaal, Lydenburg District, *Wilms* 1136 (BM). *S. leptoclada* Briq. in Bull. Herb. Boiss. ser. 2,3: 1084 (1903); Skan, l.c. 351 (1910); Ross, Fl. Natal 303 (1972). Type: Natal, Bluekrantz River, *Schlechter* 6865 (Z, holo.! ;BOL!). *S. aethiopica* sensu Letty, Wild Flow. Transv. 284, t. 141: 3 (1962); sensu Compton, Fl. Swaz. 66 (1966).

Stems shortly scabrid or tomentose to sparingly or fairly densely villous. *Leaves* petiolate, blade hispid-villous above, less so and mainly on the nerves below. *Calyx* hispid-villous.

Distribution and ecology more or less as for the species but not prevalent in the mountain grassland of the eastern Transvaal. Also occurs in Rhodesia.

TRANSVAAL.—2329 (Pietersburg): Louis Trichardt (–BB), *Breyer sub TRV 20926;* Spelonken (–BD), *Junod 123.* 2330 (Tzaneen): Tshakoma (–AB), *Obermeyer sub TRV 31569.* 2428 (Nylstroom): Geelhoutkop (–AD), *Breyer sub TRV 18105;* Sterkrivierdam Nature Reserve (–BC), *Jacobsen* 2004; Moordrift (–BD), *Leendertz sub TRV 7330;* N. of Warmbaths (–CD), *Repton 792; Sidey 1339; Smuts & Gillett 3089; Strey 3947;* Naboomfontein (–DA?), *Galpin 13481.* 2430 (Pilgrim's Rest); Ohrigstad Dam Nature Reserve (–DC), *Jacobsen 1436; 1766; 2909.* 2527 (Rustenburg): Scheerpoort (–DD), *Leendertz sub TRV 27126;* farm Uitkomst 499 (–DD), *Coetzee 654.* 2528 (Pretoria): Wonderboom Reserve (–CA), *Pole Evans 340; C. A. Smith 104; 240;* Koedoespoort (–CB), *Leendertz sub TRV 8570; Obermeyer sub TRV 27657;* Botanic Garden (–CB), *Codd 855;* 35 km E. of Pretoria (–CD), *Repton 582;* Trigaartspoort (–DB), *Bruce 97;* 18 km N.E. of Bronkhorstspruit (–DB), *Codd 2694.* 2529 (Witbank): Bundu Inn (–AC), *Mauve 4916;* Loskop Dam (–AD), *Theron 1376.* 2530 (Lydenburg); Crocodile Valley (–AD), *Burtt Davy 7662;* Nelspruit (–BD), *Liebenberg* 2596; Cythna Letty Nature Reserve (–DD), *Muller 2219.* 2531 (Komatipoort): Barberton (–CC), *Edwards 46.*

SWAZILAND.—2631 (Mbabane): Komati Bridge (–AA), *Compton 26835; 26931;* near Mbabane (–AC), *Hardy 27;* Hlatikula (–CD), *Compton 26265; 30228.*

NATAL.—2730 (Vryheid): Utrecht (CB), *Wahl sub TRV 15536.* 2732 (Ubombo): Pongola Poort (–AC), *Repton 6020.* Mpangazi (–DA), *Strey 5090;* Mbazwane (–DA), *Vahrmeijer 1133.* 2829 (Harrismith), 34 km N. of Ladysmith (–BB), *Codd 8622;* Bloukrans River (–DD), *Schlechter 6865* (Z). 2830 (Dundee): Tugela Ferry (–CD), *Galpin 14780;* Kranskop (–DD), *Galpin 14764.* 2832 (Mtubatuba): Hluhluwe Game Reserve (–AA), *Hitchins 366; 526; 643.* 2929 (Underberg): Estcourt (–BB), *West 1332; Pentz 497.* 2930 (Pietermaritzburg): near Durban (–DD), *Medley Wood 59; 6437.* 2931 (Stanger): near Verulam (–CA), *Schlechter 2894; Moll 1990.*

CAPE.—3228 (Butterworth): Kentani (–CB), *Pegler 187.*

In general the pubescence is sparingly to fairly densely villous and grades somewhat into the very densely villous pubescence of var. *galpinii*. In Natal some specimens have hispid or shortly tomentose pubescence, resembling the condition often found in *S. aethiopica*, but may be separated from that species by the 2-flowered verticils. The type of *S. leptoclada* Briq., *Schlechter* 6865 (Z) from Bloukrans River near Ladysmith is such a plant. *Schlechter* 6865 may be a mixed gathering because the specimen in PRE with this number is *S. grandifolia* E. Mey. ex Benth. or, more likely, the material may have become mixed when it was distributed. The type of *S. transvaalensis* Guerke is more densely pubescent than typical var. *natalensis*.

(b) var. **galpinii** (*Briq.*) *Codd*, stat. nov.

S. galpinii Briq. in Bull. Herb. Boiss. ser. 2,3: 1082 (1903); Skan in Fl. Cap. 5,1: 346 (1910); Compton, Fl. Swaz. 66 (1966); Ross, Fl. Natal 303 (1972). Type: Transvaal, near Barberton, *Galpin* 681 (K!, PRE!, SAM!). *S. lupulina* Briq., l.c. 1082 (1903). Type: "Natal, near Claremont, *Schlechter* 4651" (Z, holo.!; BOL!). *S. parilis* N.E. Br. in Kew Bull. 1901: 131 (1901); Skan, l.c. 347 (1910); Ross. l.c. 303 (1972). Type: Natal, Drakensberg, Tiger Cave Valley, *Evans* 387 (K, holo.; NH!). *S. villosissima* H. M. Forbes in Bothalia 4: 38 (1941); Ross, l.c. 304 (1972). Type: Natal, Entumeni, *Forbes* 783 (NH, holo.; PRE!).

Stems erect, branching from the base, 12–20 cm tall or decumbent to straggling 30–40 cm long; stem densely villous. *Leaves* subsessile or petiolate, densely villous on both surfaces. *Calyx* densely villous.

Found in dense grass, often among rocks at high and medium altitudes in central and eastern Transvaal and northern Swaziland, extending to northern Natal.

TRANSVAAL.—2428 (Nylstroom): Moorddrift (–BD), *Leendertz sub TRV 7330.* 2528 (Pretoria): Wonderboompoort (–CA), *Mogg 15860;* near Zoo (–CA), *C. A. Smith 3272;* Hennops River (–CC), *Repton 1115.* 2529 (Witbank): Middelburg (–CD), *Young A 20.* 2530 (Lydenburg): 27 km W. of Lydenburg (–AB), *Codd 8063;* Dullstroom (–AC), *Galpin 13051;* near Belfast (–CA), *Leendertz sub TRV 9178; Leistner 510;* Machadodorp (–CB), *Galpin 13109;* 18 km S.E. of Sewefontein (–CD), *Codd 8114.* 2531 (Komatipoort): near Barberton (–CC), *Galpin 681; Thorncroft sub TRV 4337; Mauve 4424.* 2630 (Carolina): near Carolina (–AA), *Bolus 12241.*

SWAZILAND.—2531 (Komatipoort): near Havelock Mine (–CC), *Miller 3033.* 2631 (Mbabane): near Mbabane (–AC), *Codd 9511; Compton 24559; 25270; 25379; 26707; 26754.*

NATAL.—2731 (Louwsburg): Pongola Experimental Farm (–BC), *Nel 199.* 2829 (Harrismith): Willowford Station (–DD), *Acocks 10599.* 2831 (Nkandla): 6 km S. of Mtonjaneni (–AD), *Codd 1808;* near Melmoth (–CB), *Mogg 4549; 6163;* Entumeni (–CD), *Forbes 783.* 2832 (Mtubatuba): Dukuduku (–AD), *Strey 5511;* Richard's Bay (–CC), *Venter 4975.*

This variety can be recognized by the combination of densely villous pubescence and 2-flowered verticils; it grades into var. *natalensis* and many specimens may be regarded as transitional between the two. In var. *galpinii* the leaves may be petiolate or subsessile and the latter specimens come near to *S. sessilifolia*, in which the lower surfaces of the leaves are densely matted-villous and the stems are softly tomentose. In *S. malacophylla* the lower surfaces of the leaves are also densely pubescent, but the verticils are usually 6-flowered. The types of *S. lupulina* Briq., *S. parilis* N.E. Br. and *S. villosissima* H. M. Forbes are not appreciably distinct from that of *S. galpinii.*

Skan, *l.c.*, draws attention to the confusion concerning the type of *S. lupulina.* Briquet cites the specimen as "Natal, Claremontplats prope Claremont, *Schlechter* 4651, ann. 1892." On the type sheet in Z and an isotype in BOL the label reads: "Claremont flats prope Cape Town, *Schlechter* 465, 9. III. 1892". It is undoubtedly conspecific with *S. natalensis* var. *galpinii*, which does not occur in the Cape, but could have been collected in northern Natal or the eastern Transvaal. Skan concluded that it had probably been introduced at the Cape but there is no evidence to support this.

8. **Stachys aethiopica** L., Mant. 1: 82 (1767); Burm. f., Fl. Cap. Prodr. 16 (1768); Ait., Hort. Kew. 2: 302 (1879); Willd., Sp. Pl. 3: 102 (1800); Thunb., Fl. Cap. ed. Schult. 447 (1823); Benth., Lab. 548 (1834); in E. Mey., Comm. 239 (1837); in DC., Prodr. 12: 476 (1848); Bol. & Wolley-Dod in Trans. S. Afr. Phil. Soc. 14: 310 (1904): Skan in Fl. Cap. 5,1: 348 (1910); Marloth, Fl. S. Afr. 3,2: 180, t. 47B (1932); Salter in Fl. Cape Penins. 697 (1950); Jacot-Guill., Fl. Lesotho 237 (1971); Ross, Fl. Natal 303 (1972). Type: Cape Province, LINN 736. 13 (lecto.).

Betonica capensis Burm. f., Fl. Cap. Prodr. 16 (1768). Type. Pluk., Almagest. Bot. t. 315, f. 3 (1696).

S. aethiopica var. *grandiflora* Burch. ex Benth. in E. Mey., Comm. 239 (1837). Type: Cape, Klein Winterhoek, *Drège* 75d (K, holo.). —var. *hispidissima* Benth., l.c. 239 (1837); Skan in Fl. Cap. 5,1: 348 (1910). Type: Cape, Hex River Kloof, *Drège* 75h (K, holo.). —var. *glandulifera* Skan, l.c. 348 (1910); Phill. in Ann. S.A. Mus. 16:244 (1917); Jacot-Guill., Fl. Lesotho 237 (1971). Syntypes: several, incl. Zwartkei River, *Baur* s.n. (K; PRE!). —var. *parviflora* Skan, l.c. 348 (1910); Salter in Fl. Cape Penins. 697 (1950). Syntypes: several, incl. Cape Peninsula, Signal Station, *Wolley-Dod* 3048 (K; BOL!). *S. pulchella* Salisb., Prodr. 83 (1796), nom. illegit. Type: based on *S. aethiopica* L. *S. serrulata* Burch. ex Benth., Lab. 549 (1834); in DC., Prodr. 12: 477 (1848); Skan, l.c. 350 (1910). Type: Cape, near Knysna, *Burchell* 5155 (K, holo.!). *S. capensis* Presl, Bot. Bemerk. 100 (1844); Skan, l.c. 366 (1910). Type: Cape, without locality, *Krebs* 273. *S. hispidula* Hochst. in Flora 66 (1845); Skan, l.c. 367 (1910). Type: Cape, Humansdorp District, *Krauss* 1125. *S. fruticetorum* Briq. in Bull. Herb. Boiss. ser. 2,3: 1083 (1903); Skan, l.c. 351 (1910). Type: Cape, Sir Lowry's Pass, *Schlechter* 1179 (Z, holo.!; BOL!). *S. harveyi* Skan, l.c. 350 (1910). Type: Cape, near Cape Town, *Harvey* s.n. (TCD, holo.). *S. attenuata* Skan, l.c. 351 (1910). Syntypes: Cape, near Bainskloof, *Bolus* 2896 (K, BOL!), Paarl Mt., *Drège* 75b (K).

Stems decumbent or ascending, up to 50 cm long or more, rather slender, sparingly to freely branched, variously pubescent with short antrorse hairs, short or long retrorse hairs often mixed with longish spreading hairs or glandular hairs, or (especially the rhachis) densely glandular-tomentulose. *Leaves* petiolate; blade broadly ovate to ovate-deltoid, usually about 0,8–3,5×0,6–2,5 cm, but up to 6×4 cm (Natal coastal form), upper surface usually shortly hispid to pilose, lower surface hispid to pilose, mainly on the nerves, often with some glands, to densely glandular-puberulous, rarely almost glabrous. *Inflorescence* usually tapering, of many whorls, occasionally with few whorls and subcapitate. *Bracts* differentiated from the leaves towards the apex. *Verticils* usually 4–6-flowered occasionally 2–3-flowered (mainly depauperate specimens). *Calyx* sparingly to densely hispid and often glandular.

Distributed from Clanwilliam District to the Peninsula and along the coast to the eastern Cape Province and to Natal, Lesotho and the Orange Free State; found in a variety of habitats from fynbos to dry woodland and coastal dune bush, extending to mountain grassland where it is usually found among sandstone rocks.

O.F.S.—2827 (Senekal): near Senekal (–BC), *Goossens 918;* near Ficksburg (–DD), *Potts 3184; Galpin 13831.* 2828 (Bethlehem): near Bethlehem (–AB), *Flanagan 2114; Phillips s.n.; Scheepers 1412; Werger 244;* Slabberts (–AC), *Stam 179;* Fouriesburg (–CA), *Potts 3265;* Clarens (CB), *Van Hoepen sub TRV 18163.* 2926 (Bloemfontein): Thaba Nchu (–BB), *Roberts 2246.*

NATAL.—2830 (Dundee): 14 km S.W. of Nqutu (–BA), *Codd 2400;* Kranskop (–DD), *Strey 4288* (NH). 2831 (Nkandla): Babanango (–AC), *King 255;* Melmoth (–CB), *Mogg 6167.* 2929 (Underberg): Tabamhlope Pasture Research Station (–BA), *West 550;* near Sani Pass (–CB), *Marias 1434.* 2930 (Pietermaritzburg): Tweedie (–AC), *Mogg 6764;* Dargle (–CA), *Hilliard and Burtt 3194;* Pietermaritzburg (–CB), *Goossens 131; Mogg 2235;* Byrne (–CC), *Galpin 11929;* Durban (–DD), *Strey 4347; 11318;* Isipingo (–DD), *Ward 3775.* 2931 (Stanger): Mt. Edgecombe (–CA), *Medley Wood 1126.* 3030 (Port Shepstone): Dumisa (–AD), *Huntley 166* (NH); Port Shepstone (–CB), *Dimock-Brown 475* (NH).

LESOTHO.—2828 (Bethlehem): Leribe (–CC), *Dieterlen 101;* Maluti Mts. (–DD), *Staples 85.* 2927 (Maseru): Teyateyaneng (–BA), *Collett 477;* Mamathes (–BB), *Jacot-Guillarmod 866; 869;* Tebetebeng River, *Jacot-Guillarmod 359;* Roma (–BC), *Ruch 1689;* Mafeteng (–CC), *Gerstner 226.* 2929 (Underberg): Sehlabathebe (–CC), *Jacot-Guillarmod, Getliffe and Mzamane 154.*

CAPE.—3027 (Lady Grey): Barkly East (–DC), *Gerstner 206.* 3028 (Matatiele): 6 km E. of Kenegha (–BC), *Story 524.* 3029 (Kokstad); 19 km N. of Swartberg (–AB), *Codd 8533;* near Kokstad (–CB), *Coleman 467;* Bizana (–DD), *Acocks 12225.* 3127 (Lady Frere): Cala (–DA), *Pegler 1646.* 3129 (Port St. Johns): Port St. Johns (–DA), *Howlett 10.* 3219 (Wuppertal): Cedarberg (–AC), *Galpin 10546;* Citrusdal (–CA), *Hanekom 1164.* 3224 (Graaff Reinet): Graaff Reinet (–BC), *Sister Francis 37.* 3225 (Somerset East): National Mountain Zebra Park (–AB), *Liebenberg 6431;* Boschberg (–DA), *MacOwan 559 partly.* 3226 (Fort Beaufort); Mungo Mt. (–CB), *Galpin 11550;* 16 km N. of Fort Beaufort (–DC), *Story 2224;* Garfield (–DD), *Acocks 23513.* 3227 (Stutterheim): Windvoëlberg (–AC), *Roberts 1798;* near Happy Valley (–AD), *Johnson 1298;* Kabaku Hills (–CB?), *Acocks 9271;* King William's Town (–CD), *Sim 19593;* near Komga (–DB), *Flanagan 414.* 3228 (Butterworth): near Mazeppa Bay (–BC), *Hilner 422;* Kentani (–CB), *Pegler 231.* 3318 (Cape Town): near Hopefield (–AB), *Letty 61;* Darling (–AD), *Bolus sub TRV 4657;* Cape Town (–CD), *Young sub TRV 26635; Mrs. Southey sub Galpin 7849;* Lions Head (–CD), *Ecklon s.n.; Marloth 65;* Camps Bay (–CD), *Thode A143;* Sea Point (–CD), *C. A. Smith 2889;* Paarl Mt. (–DB), *Kruger* M118; near Stellenbosch (–DB), *Parker 3895; Bos 135; Kerfoot 6081.* 3319 (Worcester): near Gouda (–AC), *Esterhuysen 18787;*

Prospect Peak (–BC), *Esterhuysen 15902;* Gydouw (–AD), *Leipoldt s.n.;* Veld Reserve (–CB), *Olivier 35;* French Hoek Pass (–CC), *Boucher 2343;* near McGregor (–DD), *Van Breda & Joubert 1973.* 3322 (Oudtshoorn): between Wilderness & Knysna (–DC), *Wells 3723.* 3323 (Willowmore): near Joubertina (–DD), *Van Breda 1168.* 3325 (Port Elizabeth): near Kenkelbosch (–DB), *Archibald 5995; Paterson 55;* Port Elizabeth (–DC), *Borle 15.* 3326 (Grahamstown): Alicedale (–AC) *Rogers 12016;* Port Alfred (–DB), *Tyson s.n.; Rogers 16654;* Kowie (–DB), *Britten 810.* 3327 (Peddie): East London (–BB), *Galpin 1879.* 3418 (Simonstown): Hout Bay Nek (–AB), *Hutchinson 103;* Muizenberg (–AB), *Pillans 3678.* 3419 (Caledon): Enon (–AB), *Thode A2741.* 3420 (Bredasdorp): National Bontebok Park (–AB), *Liebenberg 6431;* Kompanjies River (–AB), *Marsh 581;* De Hoop (–AD), *Van der Merwe 1158;* Fort Beaufort (–BD), *Marsh 820;* Nachtwacht (–CA), *C. A. Smith 3053.* 3423 (Knysna): Keurboomstrand (–AB), *Codd 3565.*

Skan attempted to reduce the confusion which existed in this complex by isolating certain discordant elements as separate species, and by upholding four varieties within *S. aethiopica.* With the advent of a good deal of modern material, the position is still confused, but it appears that a broader concept of the species should be adopted, while the separation of varieties within *S. aethiopica* seems scarcely justified.

Several of the peripheral species upheld by Skan are still maintained, such as *S. rudatisii, S. graciliflora* (=*S. cooperi*), *S. scabrida* (=*S. priorii*), *S. flexuosa, S. cymbalaria* and *S. sublobata,* and the distinguishing characters are discussed under the respective headings. Others, such as *S. harveyi, S. serrulata, S. attenuata* and *S. fruticetorum* are now included in *S. aethiopica.*

Regarding the typification of *S. aethiopica,* Linnaeus refers to Pluk., Alm. 245, t. 315, f. 3, while the description indicates that he had a specimen before him. Of these two elements, the specimen in the Linnaean Herbarium No. 736.13 may be regarded as the type and is a plant with retrorse to spreading pubescence and lacking glandular hairs. In both elements the plant referred to has 2-flowered verticils, but this must be regarded as exceptional as most specimens which match the type have 2–6-flowered verticils. The typical form occurs mainly in the south-western Cape Province, but it grades into the varieties upheld by Skan.

Bentham based his var. *hispidissima* on a *Drège* gathering with denser and more stiffly spreading hairs on stems and leaves, but this is scarcely distinct from the typical form. The other two varieties, described by Skan, are possibly more distinct but, due to the many intermediates, it is preferred to regard them as forms rather than give them taxonomic rank.

In the plants placed by Skan in var. *parviflora*, the hairs on the stem are antrorse and shortly scabrid, the petioles tend to be shorter and the flowers smaller. Salter in Fl. Cape Penins. 697 (1950) upheld this variety but, as one moves away from the Peninsula, the distinction becomes less clear.

The form separated as var. *glandulifera* is usually recognizable under magnification by the glandular-puberulous pubescence on most parts of the plants, especially the under-surface of the leaf, the rhachis and the calyx. It appears to be the prevalent form in the eastern, summer-rainfall part of South Africa, especially along the Drakensberg escarpment. Towards the west it grades into typical *S. aethiopica* and the type of *S. fruticetorum, Schlechter* 1179 from Sir Lowry's Pass, is an intermediate specimen.

Another form has been observed along the coast of Natal in which the leaves are much larger than usual, up to 6×4 cm. It appears to be a semi-weed in disturbed areas, and serious consideration was given to according it separate status of some sort. However, there is a gradation in leaf size and many intermediate specimens cannot be allocated with certainty. At present it is regarded as a form growing under favourable subtropical conditions. The pubescence is somewhat similar to the plants discussed under var. *glandulifera.*

To summarize, the pubescence in *S. aethiopica* is mainly hispid, either antrorse, retrorse or spreading, sometimes with scattered longish hairs and often finely glandular, especially on the calyx and under-surface of the leaves. This can usually be distinguished from the villous pubescence of *S. natalensis* but there should be no confusion between the two because, in the eastern summer-rainfall areas, *S. aethiopica* always has 4–6-flowered verticils, while *S. natalensis* is strictly 2-flowered. The two overlap in Natal and the extreme eastern Cape Province. *S. aethiopica* is absent from the Transvaal and rare in Swaziland, but a very glandular form occurs in Lesotho and the eastern Orange Free State.

As it often happens in variable species, *S. aethiopica* tends to be a repository for specimens which cannot satisfactorily be placed elsewhere. For example, a few specimens of rather distinct facies, with stiff stems and very densely glandular-puberulous stems, leaves and calyces, but with 2-flowered verticils, have been collected in the eastern Cape Province, namely: Stutterheim District, *Acocks* 2971 and *Sim* s.n.; Port St. Johns District, *Flanagan* 2595. If *S. aethiopica* were divided into formal varieties, these specimens would probably be worthy of varietal rank.

S. aethiopica normally has a slender tapering inflorescence of several to many verticils. On the other hand some specimens in the southern Cape Province have few verticils with an almost subcapitate inflorescence, resembling the condition found in *S. graciliflora* (=*S. cooperi*) and to some extent in *S. scabrida.* The plants previously included in *S. cooperi* usually have larger leaves, while those described as *S. scabrida* have subglabrous to sparingly retrorse-scabrid stems and subglabrous leaves. The type of *S. graciliflora* is somewhat intermediate but it seems possible to maintain all three species, though occasional specimens, especially from the Knysna–Tsitsikama area, may be difficult to place with certainty (see next species).

9. **Stachys graciliflora** *Presl,* Bot. Bemerk. 100 (1844); Benth. in DC., Prodr. 12: 496 (1848); Skan in Fl. Cap. 5,1: 366 (1910) Type: Cape, without locality, *Krebs* s.n. (PRC, holo.!, as to left-hand specimen on sheet labelled *S. graciliflora* Presl; PRE, photo.).

S. cooperi Skan in Kew Bull. 1909: 420 (1909); Fl. Cap. 5,1: 343 (1910); Ross, Fl. Natal 303 (1972). Syntypes: Cape, Albany Division, *Cooper* 15(K!); Kentani, *Pegler* 908, collected April 1909 (K!, PRE!).

Stem shortly and often sparingly retrorse-pubescent. *Leaves* petiolate, blade ovate to broadly ovate, often thin-textured, 2–6,5×1,4–5 cm, eglandular, sparingly hispidulous or shortly and sparingly pilose, the hairs on the upper leaf surface soft and not bulbous-based. *Inflorescence* of 1–4 (rarely more) verticils, somewhat lax below or often subcapitate, verticils 4–6-flowered; bracts differentiated towards the apex. *Calyx* sparingly or softly hispid, eglandular.

A soft straggling herb of moist places in forest margins, in grass, fynbos or coastal scrub from southern Natal to Knysna in the Cape.

NATAL.—3030 (Port Shepstone): Horseshoe Farm (–CC), *Strey 6169.*

CAPE.—3129 (Port St. Johns): Umgazi River Mouth (–CB), *Wells 3494.* 3226 (Fort Beaufort): Katberg (–BC), *Galpin 2069.* 3227 (Stutterheim): Pirie Forest (–CC), *Sim A; Acocks 9284;* near Komga (–DB), *Flanagan 1752.* 3228 (Butterworth): Kentani (–CB), *Pegler 908.* 3322 (Oudtshoorn): Wilderness (–DC), *Van Niekerk 236.* 3325 (Port Elizabeth): Addo National Park (–BC), *Brynard 363.* 3423 (Knysna): Knysna: (–AA), *Keet 635;* Keurboomstrand (–AB), *Fourcade 6119; Taylor 4914;* Storms River Mouth (–BB), *Liebenberg 7765.* 3424 (Humansdorp): Humansdorp (–BB), *Galpin 4427.*

There is a gradation in leaf size from the specimens with larger and softer leaves, described as *S. cooperi* Skan, to those occurring further west with smaller and firmer leaves, which match the type of *S. graciliflora* Presl. The stem pubescence of the latter tends to be slightly more scabrid and thus approaches the condition found in *S. scabrida* Skan (see below). However in *S. scabrida* the leaves are somewhat thicker in texture, dry dark brown and the hairs on the upper leaf surface are thicker with distinctly swollen bases. On these grounds *S. scabrida* is kept distinct, but the two overlap from southern Transkei to Knysna and further study in this area is required.

As mentioned under the previous species, *S. aethiopica* sometimes has few, fairly condensed verticils which resemble those of *S. graciliflora.* However, these plants usually have a coarser pubescence on the stems, while gland-dots are often present on the calyx and on the lower surface of the leaves. No glandular hairs are found in *S. graciliflora.*

Specimens with large leaves resemble *S. tubulosa* MacOwan, a species not included in the present treatment, but may be separated, when flowers are available, by the shorter corolla tube which does not exceed 10 mm in length. In *S. tubulosa* the corolla tube is 12–18 mm long and the species has a more northerly distribution from East Griqualand to Swaziland.

10. **Stachys scabrida** *Skan* in Fl. Cap. 5,1: 349 (1910). Lectotype: Cape, Bruintjieshoogte, *Burchell* 3037 (K, lecto.!; PRE!).

S. priorii Skan, l.c. 353 (1910). Type: Cape, Algoa Bay, *Prior* s.n. (K, holo.!).

Stems subglabrous to scabrid with few strong retrorse-scabrid hairs to longer scattered multicellular retrorse hairs. *Leaves* petiolate, firm-textured and usually drying dark brown, ovate to ovate-deltoid, 1,2–3×0,8–2 cm, subglabrous to sparingly hispid, the upper surface with scattered short to longish bulbous-based hairs. *Inflorescence* fairly slender, of few verticils, spaced below; bracts differentiated towards the apex. *Calyx* sparingly hispid, eglandular.

A straggling herb in grass, fynbos or coastal scrub, extending from the southern Transkei to Knysna and, inland, to Steynsburg and Somerset East Districts.

CAPE.—3125 (Steynsburg): Suurberg (–BD), *Schonland 3177.* 3225 (Somerset East): Bruintjieshoogte (–CB), *Burchell 3037.* 3227 (Stutterheim): Hanover (–CD), *Sim s.n.* 3228 (Butterworth): "Gekau" River (–BC?), *Drège s.n.* (K). 3324 (Steytlerville): Assegaibosch (–CD), *Breyer sub TRV 23323;* 20 km W. of Cambria (–DA), *Story 2445.* 3325 (Port Elizabeth): Van Stadens Mts. (–CC), *Zeyher 831* (K); Perseverance (–DC), *Long 816.* 3326 (Grahamstown): Coldspring (–AD), *Gane sub TRV 25270;* near Grahamstown (–BC), *MacOwan 559,* partly. 3423 (Knysna): (–AA), *Breyer. sub TRV 23365.*

S. scabrida appears to be related to *S. graciliflora,* but the pubescence is coarser and more scabrid, while the leaves are thicker-textured and the hairs on the upper leaf surface tend to be bulbous-based. The inflorescences tend to be more slender, rather than subcapitate, as in *S. graciliflora.* The distinction is by no means clear-cut, as indicated in the discussion of the latter species, and specimens such as *Story* 2445 tend to be somewhat intermediate.

11. **Stachys cymbalaria** *Briq.* in Bull. Herb. Boiss. ser. 2,3: 1088 (1903); Skan in Fl. Cap 5,1: 352 (1910); Ross, Fl. Natal 303 (1972). Type: Cape, Cradock, *Cooper* 416 (K, holo.!; W!).

S. aethiopica L. var. *tenella* Kuntze, Rev. Gen 3,2: 262 (1898). Type: Cape, Cradock, *Kuntze* s.n. *S. cymbalaria* var. *alba* Skan, l.c. 352 (1910). Type: Natal, Richmond, *Medley Wood* 1846 (K, holo.; NH!).

Stems slender, wiry, subglabrous or with a few long slender spreading hairs or occasionally shortly glandular-pubescent. *Leaves* petiolate, blade small, broadly ovate-deltoid to suborbicular, 8–15×6–12 mm, subglabrous to thinly appressed-pubescent or glandular-puberulous. *Inflorescence* lax of 1–5 verticils; verticils 2-flowered; bracts differentiated, the upper shorter than the calyx. *Calyx* puberulous to hispidulous.

Found among rocks in exposed mountain grassland, at altitudes of 1 000–1 800 m; recorded from a few disjunct localities in southern Natal and the eastern Cape Province.

NATAL.—2930 (Pietermaritzburg): Zwartkop (–CB), *Medley Wood 11120;* Richmond (–CD), *Medley Wood 1846* (NH). 3029 (Kokstad): Ngeli area (–DA), *Hilliard & Burtt 5834* (NU); *7554* (NU); *Strey 6337* (NH).

CAPE.—3039 (Kokstad): Mt. Insizwa (–CB), *Schlechter 6467; Hilliard & Burtt 6568.* 3224 (Graaff Reinet): Reitvlei (–AB), *Galpin 10011;* Lootsberg Pass (–BD), *Acocks 13546.* 3225 (Somerset East): Mountain Zebra National Park (–AD), *Brynard 295; Liebenberg 7107.*

The species is closely related to *S. aethiopica* but is characterized by the many wiry stems radiating from the apex of a slender taproot, the small ovate to roundish leaves and the 2-flowered verticils.

12. **Stachys sublobata** *Skan* in Fl. Cap. 5,1: 354 (1910). Lectotype: Cape, Swellendam District, Barrydale, *Galpin* 4425 (K, lecto.; PRE!).

Stems slender, sparsely hispidulous, occasionally with some longish spreading hairs. *Leaves* petiolate, blade small, narrowly triangular, 10–15×4–6 mm, thickish in texture, sparingly hispidulous on both surfaces, sometimes with gland-dots below, margin deeply crenate or almost lobed with 3–5 lobe-like teeth. *Inflorescence* lax of 2–5 verticils; verticils 2–(or rarely 6–) flowered; bracts leaf-like below, differentiated towards the apex. *Calyx* thinly glandular-hispid.

Found on hillsides in fynbos at altitudes of 300–900 m in the south-western Cape Province; known from a few localities between Caledon and Mossel Bay and, inland, to Ladismith and Oudtshoorn Districts.

CAPE.—3320 (Montagu): Barrydale (–DC), *Galpin 4425.* 3321 (Ladismith): Rooiberg Pass (–DA), *Acocks 20779.* 3322 (Oudtshoorn): Cango Caves (–AC), *Bolus 12244.* 3419 (Caledon): 10 km W. of Rietpoel Station (–BD), *Acocks 22582.* 3421 (Riversdale): Klein Berg (–BB), *Galpin 4426,* partly.

This species resembles *S. cymbalaria* and, like that species, is closely related to *S. aethiopica,* but can be recognized by the narrowly triangular leaves, rather thickish in texture and with deeply crenate, almost lobed margins. It normally has 2-flowered verticils, but one portion of *Galpin* 4426 in PRE, which matches *S. sublobata,* has 6-flowered verticils. The other specimen mounted on the same sheet has larger leaves and is *S. aethiopica.*

13. **Stachys flexuosa** *Skan* in Fl. Cap. 5,1: 352 (1910). Type: Cape, Stockenstroom District, old Katberg Pass, *Galpin* 2393 (wrongly listed in Fl. Cap. as 2093) (K, holo.; PRE!, SAM!).

Stems fairly densely villous-pilose with long spreading hairs and some short glandular hairs. *Leaves* petiolate, blade ovate, 1–2×0,6–1,5 cm, somewhat appressed-villous with some bulbous-based hairs above, hispid mainly on the nerves below, base not deeply cordate. *Inflorescence* fairly dense, of few to several 2–6-flowered verticils; bracts leaf-like below, becoming smaller towards the apex. *Calyx* hispid, often with some glands.

Known from a few localities in the eastern Cape Province, among rocks in mountain grassland.

Cape.—3126 (Queenstown): near Hopewell (–DC?), *Galpin 8379*. 3129 (Port St. Johns): Port St. Johns District (CB?), *Swinny & Baker sub TRV 14143*. 3226 (Fort Beaufort): old Katberg Pass (–BC), *Galpin 2393;* Hogsback (–DB), *Rattray 403*.

The species is included here because the small ovate leaves with a rather wide sinus at the base are reminiscent of the *S. aethiopica* complex, but the relationship appears to be with another complex which includes *S. obtusifolia* and *S. tysonii*. From these it differs mainly in the smaller leaves, and less densely villous stems and leaves, in contrast to the markedly glandular pubescence of *S. tysonii*. As in many other species of *Stachys*, a good deal more material is required before the status of *S. flexuosa* can be reliably determined.

UITTREKSEL

Die Stachys aethiopica-*kompleks word ondersoek en 'n sleutel voorsien tot die soorte wat erken word. Die kombinasie* S. natalensis *Hochst. var.* **galpinii** (*Briq.*) *Codd word gemaak en twee nuwe soorte,* S. **reticulata** *Codd en* S. **arachnoidea** *Codd word beskryf.*

Bothalia 12,2: 191–194 (1977)

New taxa and a new combination in the genus *Cotyledon*

H. R. TÖLKEN*

ABSTRACT

Five new species and one variety are described and the combination *Cotyledon tomentosa* Harv. subsp. **ladismithiensis** (V. Poelln.) Toelken is effected. The following new names are published; C. **sulphurea** Toelken, *C.* **occultans** Toelken, *C.* **similis** Toelken, *C.* **viridiflorum** Toelken, *C.* **hallii** Toelken and *C. pygmaea* Barker var. **tenuis** Toelken.

RESUME

NOUVEAU TAXA ET NOUVELLE COMBINAISON DANS LE GENRE COTYLEDON

On décrit cinq espèces et une variété nouvelles. La combinaison Cotyledon tomentosa *Harv. subsp.* **ladismithiensis** *(V.Poelln.) Toelken est opérée. Les nouveaux noms publiés sont:* C.**sulphurea** *Toelken,* C.**occultans** *Toelken,* C.**similis** *Toelken,* C.**viridiflorum** *Toelken,* C.**hallii** *Toelken et* C.pygmaea *Barker var.* **tenuis** *Toelken.*

Recent collecting has added more information to the knowledge of some rare species of *Cotyledon* from the north-western Cape Province, so that these can now be described. This has also allowed a re-evaluation of the delimitation of other species, which were previously differently interpreted.

1. **Cotyledon sulphurea** *Toelken*, sp. nov. a *C. occultante* foliis glabris, florescentia praecociore et ovulis ovatis differt.

Herbae perennes tuberibus subterraneis ramosis usque ad 10 cm longis, ramis succulentis laevibus pauciramosis et rare 2 cm longioribus. *Folia* alterna, oblanceolata vel spathulata, 0,5–2,5 cm longa, 0,2–0,5 cm lata, cuneata, plerumque obtusa, dorsoventraliter, complanata, leviter sulcata supra et convexa subtus, glabra sed cellulis pustuliformibus, succulenta, viridia. *Inflorescentia* thyrsus corymbiformis 1–4 dichasiis patentibus, pedunculo rigido 1–3 (–5) cm longo et tecto pilis glandulosis, pedicello 0,4–0,8 cm longo et tecto pilis glandulosis, bracteis lanceolatis deciduis. *Sepala* triangulari-lanceolata, 0,35–0,45 cm longa, acuta, tecta sparsim pilis glandulosis patentibus, succulenta, flavo-virentia. *Petala* oblonga, 1,3–1,5 cm longa, acuta, connata in tubo 0,8–1 cm longo, tecta plus minusve etiam pilis glandulosis patentibus extus et pilis aliquot tenuis intus praecipue tubi petalorum in partibus inferis, sulphurea. *Stamina* 1–1,2 cm longa et aequilonga, antheris 0,1–0,12 cm longis et filamentis rectis pilis patentibus praecipue in partibus quibus connatis petalorum tubo. *Squamae* oblongae 0,1–0,13 × 0,02–0,04 cm, plus minusve emarginatae, leviter succulentae, flavae. *Carpella* ovariis gracilibus gradate constricta ad stylos erectos et stigmatibus terminalibus; ovarium 10–14 ovulis ovatis sine porcis verticalibus.

Type: Cape: near Pofadder, *Tölken* 3676A (BOL, holo.!).

Perennial with branched underground tubers up to 10 cm long, with fleshy glabrous stems little branched and rarely longer then 2 cm. *Leaves* alternate, oblanceolate to spathulate, 0,5–2,5 cm long, 0,2–0,5 cm broad, cuneate, usually obtuse, dorsiventrally compressed and slightly grooved above and convex below, succulent, glabrous but with some large bulging epidermal cells, green. *Inflorescence* a flat-topped thyrse with one to several spreading monochasia, with wiry peduncle 1–3 (–5) cm long and covered with glandular hairs, with pedicels 0,4–0,8 cm long and covered with glandular hairs, with lanceolate bracts deciduous. *Sepals* triangular-lanceolate, 0,35–0,45 cm long, acute, sparsely covered with glandular hairs, succulent, yellowish-green. *Petals* oblong 1,3–1,5 cm long, acute, fused into a tube 0,8–1 cm long, more or less evenly covered with spreading glandular hairs on the outside and with few fine hairs on the inside mainly where the filaments are fused to the petal-tube, sulphur-yellow. *Stamens* 1–1,3 cm long and all of equal length, with anthers 0,1–0,12 cm long, with straight filaments, with scattered hairs mainly where fused to the petal-tube. *Squamae* oblong 0,1–0,13 × 0,02–0,04 cm, more or less emarginate, slightly succulent, yellow. *Carpels* with slender ovaries gradually constricted into erect styles with terminal stigmas; ovary with 24–40 ovate ovules without distinct vertical ridges.

This species is usually found on quartzite gravel on the lower slopes of hills and has been recorded only from the vicinity of Pofadder, but here it is locally common. It flowers during November and December, a distinguishing feature between this species and *C. occultans*.

CAPE.—2919 (Pofadder): 4 km N.E. of Pofadder (–AB), *Horn 1011* (NBG); *Horn sub NBG 873/61* (NBG); near Pofadder (–AB), *Tölken 3676A* (BOL); *Wisura 1961* (NBG); 11 km S.E. of Pofadder (–AB), *Tölken 3679A* (BOL).

2. **Cotyledon occultans** *Toelken*, sp. nov. a *C. sulphurea* foliis paene orbicularibus quibus tectis pilis glandulosis et florescentia serotinioribus; a *C. pygmaea* ramo brevissimo et trichotomatibus unicellularibus.

Herbae perennes tuberibus subterraneis pauciramosis usque ad 6 cm longae, ramis laevibus pauciramosis et usque ad 1 cm longis. *Folia* alterna, spathulata vel orbicularia, 0,4–1,2 cm longa, 0,3–1,4 cm lata, cuneata vel paene petiolata, obtusa, dorsiventraliter complanata et leviter sulcata supra, tecta dense trichotomatibus erectis obtusis, succulenta, atrovirentia. *Inflorescentia* thyrsus 1 (–3) monochasiis 1–3 floribus, pedunculo rigido 0,8–1,5 cm longo et tecto pilis glandulosis, pedicello 0,5–1,3 cm longo et tecto pilis glandulosis, bracteis lanceolatis caducis. *Sepala* triangulari-lanceolata, 0,2–0,3 cm longa, acuta, tecta pilis glandulosis, succulenta, viridia. *Petala* oblonga, 1–1,2 cm longa, acuta, connata in tubo 0,6–0,8 cm longo, plus minusve etiam tecta pilis glandulosis extus et pilis aliquot tenuibus intus praecipue in partibus inferis tubi petalorum. *Stamina* 1,1–1,4 cm longa et aequilonga, antheris 0,1–0,12 cm longis, filamentis rectis pilis tenuibus sparsis praecipue in partibus quibus connatis petalorum tubo. *Squamae* oblongae, 0,11–0,13 × 0,02–0,04 cm, plerumque plus

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria

minusve emarginatae, succulentae, flavae. *Carpella* ovariis gracilibus gradate constrictis ad stylos erectos stigmatibus terminalibus; ovarium 10–14 ovulis ovatis sed lateriobus ad lateres et porcis verticalibus.

Type: Cape, near Bitterfontein, *H. Hall* 4289 (PRE, holo.!; NBG).

Perennial with little branched underground tubers up to 6 cm long, with short glabrous stems little branched and up to 1 cm long. *Leaves* alternate, spathulate or orbicular, 0,4–1,2 cm long, 0,3–1,4 cm broad, cuneate or almost petiolate, obtuse, dorsiventrally compressed and slightly grooved above, densely covered with blunt erect trichomes, deep green. *Inflorescence* a thyrse with 1 (–3) monochasia, each with 1–3 flowers, with wiry peduncle 0,8–1,5 cm long and covered with glandular hairs, with pedicels 0,5–1,3 cm long and covered with glandular hairs, with lanceolate deciduous bracts. *Sepals* triangular-lanceolate, 0,2–0,3 cm long, acute, covered with glandular hairs, succulent, green. *Petals* oblong, 1–1,2 cm long, acute, fused into a tube 0,6–0,8 cm long and more or less evenly covered with spreading glandular hairs on the outside and with a few fine hairs on the inside mainly where the filaments are fused to the petal tube, pale yellow or yellowish-green. *Stamens* 1,1–1,4 cm long and about equally long, with anthers 0,1–0,12 cm long, with straight filaments with fine hairs mainly where fused to the petal tube. *Squamae* oblong, 0,11–0,13×0,02–0,04 cm, usually more or less emarginate, fleshy, yellow. *Carpels* with slender ovaries gradually constricted into erect styles with terminal stigmas; ovary with 8–20 ovules almost dumbell-shaped and with distinct vertical ridges.

So far this small *Cotyledon* has been recorded from quartzite gravel near Bitterfontein and Steinkopf, but the fact that these two localities are so far away from each other suggests that the species is probably widely distributed over the little known eastern foothills of the Kamiesberg. Mr H. Hall, the very observant collector, was the first to draw attention to this small plant. In addition, the species flowers in February and March, the driest period in the Namaqualand, so that it is rarely seen in flower.

Cape.—2917 (Springbok): 11 km S. of Steinkopf (–BD), *Tölken 4272* (BOL). 3118 (Vanrhynsdorp): near Bitterfontein (–AB), *H. Hall 3960* (PRE): *4289* (NBG, PRE).

3. **Cotyledon pygmaea** *Barker* in Flow. Pl. S. Afr. 10: t. 396 (1930). Type: Cape, Vanrhynsdorp, Vigne sub NBG 2267/29 (K, holo!).

var. **pygmaea.**

Stems robust and usually (0,4–) 0,5–1 cm in diameter, with pale yellow rarely greyish bark which is smooth or peeling in older plants. *Leaves* densely covered with heart-shaped trichomes. *Squamae* transversely oblong to square, 0,08–0,1×0,1–0,13 cm.

Characteristic of *C. pygmaea* are the multicellular trichomes which consist of two larger basal cells and a smaller glandular cell at the apex. The basal cells are bulging which gives them the heart-shaped appearance at least on the leaves of var. *pygmaea*. The petals are covered with trichomes with oblong basal cells and the terminal cell is very small. The latter type of trichomes are found on all parts of the plants of var. *tenuis*.

Although extreme forms of the two varieties may differ in several characters such as the diameter of stems and their bark, a considerable range of variation has been recorded and both varieties were found near Koekenaap. The plant of the typical variety (Hall sub NBG 587/54) from that area shows somewhat intermediate characters, but its pollen shows no abnormality to indicate that the two varieties hybridize in this region.

var. **tenuis** *Toelken*, var. nov., a var. *pygmaea* squamis oblongis differt.

Caules tenues 0,2–0,3 (–0,4) cm in diametro, cortice griseo plus minusve porcata et non chartaceo. *Folia* trichotomibus oblongis sparsim tecta. *Squamae* oblongae 0,09–0,12×0,04–0,06 cm.

Type: Cape, near Holrivier Station, *H. Hall* 3925 (PRE, holo.!; NBG!).

Stems slender 0,2–0,3 (–0,4) cm in diameter, with grey bark more or less ridged and not peeling. *Leaves* sparsely covered with erect oblong trichomes. *Squamae* oblong 0,09–0,12×0,04–0,06 cm.

Cape.—3118 (Vanrhynsdorp): near Holrivier Station (–AD), *Hall 3925* (NBG, PRE): *4273* (PRE); Koekenaap (–CB), *Hall 2786* (NBG); *Hall sub NBG 72/56* (NBG); Vanrhynsdorp (–DB); *Compton et al sub NBG 842a/48* (NBG).

4. **Cotyledon similis** *Toelken*, sp. nov. a *C. pygmaea* foliis glabris et pilis longissimis in fauce tubi petalorum differt.

Herbae perennes tuberibus subterraneis pauciramosis usque ad 5 cm longis, caulibus erectis rare remosis et usque ad 12 cm longis et usque ad 0,4 cm in diametro, griseis et porcis nigris verticalibus. *Folia* alterna, elliptica vel oblonga, 0,5–1,3 cm long, 0,2–0,4 (–0,5) cm lata, acuta vel obtusa, teretia vel leviter complanata, glabra sed cellulosis pustuliformibus, viridia et saepe rufo-striata. *Inflorescentia* monochasium 1 (–3) floribus, pedunculo glabro 0,8–3 cm longo, pedicello glabro 0,4–0,6 cm longo, bracteis lanceolatis deciduis. *Sepala* triangulari-lanceolata, 0,15–0,25 cm longa, acuta, glabra, succulenta, viridia. *Petala* oblonga, 0,8–1 cm longa, acuta, connata in tubo 0,6–0,8 cm longo, extus glabra et intus pilis longis tenuis praecipue in fauce tubi petalorum, pallide flavo-virentia vel eburnea. *Stamina* 0,7–1 cm longa et aequilonga, antheris 0,08–0,1 cm longis, filamentis rectis pilis patentibus praecipue in partibus quibus connatis tubo petalorum. *Squamae* anguste oblongae, 0,12–0,14×0,02–0,03 cm, plerumque penitus emarginatae, leviter succulentae, croceae ad flavam. *Carpella* ovariis gracilibus gradate constricta ad stylos erectos et stigmatibus terminalibus; ovarium 10–14 ovulis ovatis sed latioribus ad lateres et porcis verticalibus.

Type: Cape, N. of Grootmis, *Wisura* 1303 (NBG, holo!).

Perennial with branched underground tubers up to 5 cm long, each with an erect stem; stems rarely branched, up to 12 cm long and up to 0,4 cm in diameter, grey with black vertical ridges. *Leaves* alternate, elliptic to oblong 0,5–1,3 cm long, 0,2–0,4 cm broad, acute or obtuse, terete or almost so, glabrous but with irregularly bulging epidermal cells, green, often with reddish-brown stripes. *Inflorescence* a monochasium with 1 (–3) flowers, with glabrous peduncle 0,8–3 cm long, with glabrous pedicels 0,4–0,6 cm long, with deciduous lanceolate bracts. *Sepals* triangular-lanceolate, 0,15–0,25 cm long, acute, glabrous, succulent, green. *Petals* oblong, 0,8–1 cm long, acute, fused into a tube 0,6–0,8 cm long, glabrous on the outside and with long fine hairs in the throat of the petal tube, pale yellowish-green to cream. *Stamens* 0,7–1 cm long and all about the same length, with anthers 0,08–0,1 cm long, with straight filaments with spreading hairs mainly where fused to the petal tube. *Squamae* narrowly oblong, 0,12–0,14×0,02–0,03 cm, usually deeply emarginate, slightly fleshy, orange to yellow.

Carpels with slender ovaries gradually constricted into erect styles and terminal stigmas; ovary with 10–14 ovules almost dumbell-shaped and with vertical ridges.

Plants of this species were found either in east-facing crevices on exposed rock ledges or on quartzite gravel on hills mainly west of the mountains between Komaggas and the Orange River.

The slender grey stems bear leaves only for a very short period, so that this delicate plant is easily overlooked. The slender stems are superficially similar to those of *C. pygmaea* var. *tenuis*.

Cape.—2816 (Oranjemund): Numees mountain (–BD), *Tölken 3312* (BOL); Holgat River (–DB), *Tölken 1857* (BOL). 2917 (Springbok): Augrabies (–AA), *Hall 1362A* (NBG); N. of Grootmis (–AC), *Wisura* 1303 (NBG); 48 km S.E. of Port Nolloth (–AC), *Acocks 14235* (PRE); 46 km E. of Port Nolloth (–AD), *M. Schlechter sub SUG 6870* (BOL); Ratelpoort (–BD), *Littlewood sub (NBG) 434/69* (NBG); Komaggas (–CD), *Tölken 2026* (BOI).

5. **Cotyledon viridiflorum** *Toelken*, sp. nov. a *C. fragile* petalis pubescentibus intra et extra et foliis dorsoventraliter complanatis glabrescentibus differt.

Fruticuli basis tuberosis, ramis paucis succulentis usque ad 35 cm longis, erectis, tectis pilis grandulosis glabrescentibus. *Folia* alterna, oblanceolata vel elliptica, 2–4 cm longa, 0,8–1 cm lata, cuneata, plerumque apicibus obtusis, dorsiventraliter complanata et leviter sulcata supra, tecta pilis glandulosis vel glabrescentia, succulenta, viridia. *Inflorescentia* thyrsus spiciformis (1–) 3–5 floribus, pedunclo 0,8–4 cm longo et pedicello glabro 0,5–1 (–2,5) cm longo, bracteatis squamosis. *Sepala* triangulari-lanceolata, 0,5–0,6 (–1) cm longa, acuta, tecta pilis glandulosis patentibus, succulenta, viridia. *Petala* oblonga, 2,4–2,6 cm longa, acuta, connata in tubo 1,8–2 cm longo, apicibus recurvis, tecta pilis plus minusve glandulosis intra et extra, leviter succulenta, viridia vel flavovirentia. *Stamina* 1,4–1,9 cm longa, antheris nigris 0,4–0,6 cm longis, filamentis pilis patentibus et saepe flexibus infra antheras. *Squamae* oblongae, 0,1–0,12×0,03–0,05 cm, leviter emarginatae, succulentae, flavae. *Carpella* 1,2–1,5 cm longa, ovariis gracilibus gradate constrictis ad stylos erectos stigmatibus terminalibus; ovarium 8–12 ovulis elongato-ovatis porcis verticalibus.

Type: Cape, near Modderfontein, *Tölken* 5327 (PRE, holo!).

Shrublet with tuberous bases, with few brittle fleshy branches up to 35 cm long, erect, covered at first with glandular hairs, later glabrescent. *Leaves* alternate, oblanceolate to elliptic, 2–4 cm long, 0,4–1 cm broad, each with cuneate base and obtuse apex, dorsiventrally compressed and slightly grooved above the central vein, covered with glandular hairs when young becoming glabrous later. *Inflorescence* a spike-like thyrse with (1–) 3–5 flowers, with peduncle 0,8–4 cm long and pedicels 0,5–1 (–1,5) cm long, with scale-like bracts. *Sepals* triangular-lanceolate, 0,5–0,6 (–1) cm long, acute covered with spreading glandular hairs, succulent, green. *Petals* oblong 2,4–2,6 cm long, acute, fused into a tube 1,8–2 cm long, with apices recurved or recoiling, covered with recurved hairs, more or less glandular on the outside and inside, slightly fleshy, yellowish-green. *Stamens* 1,4–1,9 cm long, with black anthers 0,4–0,6 cm long, filaments with spreading hairs and often with right-angled outward bend below anthers. *Squamae* oblong 0,1–0,12× 0,03–0,05 cm, slightly emarginate fleshy, yellow. *Carpels* with slender ovaries gradually constricted into erect styles with terminal stigmas; ovary with 8–12 ovules with vertical ridges. Like *C. fragilis* and *C. vetricosa*, this species grows in the shade of overhanging rocks and usually on the south aspect of mountains.

Cape.—2817 (Vioolsdrif): near Modderfontein (–CC), *Tölken 5327* (PRE).

6. **C. hallii** *Toelken*, sp. nov. a *C. pearsonio* habitato erecto-fastigiato et usque ad 40 cm alto, foliorum cicatricibus paene indistinctis et floribus erectis differt.

C. pearsonii sensu Jacobsen, Hand, Succ. Pl. 1: 289, fig. 286 (1960); Sukk. Lex. 135, t. 40, 5 (1970), non Schonl. *C. racemosa* sensu Friedr. in Prodr. Fl. S.W. Afr. 52: 10 (1968), non Harv.

Fruticuli perennes caulibus succulentis usque ad 5 cm in diametro et leviter ventricosis ad basim, multiramosi et ramis erectis vel paene fastigiata. *Folia* alterna, lineari-lanceolata, 0,8–3,5 cm longa, 0,3–0,5 cm lata, acuta, teretia vel interdum sulcata supra, sparsim tecta pilis glandulosis sed glabrescentia, viridia vel glaucescentia. *Inflorescentia* thyrsus 1–4 monochasiis, pedunculo lignescente 1,5–3,5 cm longo, pedicello tenace 1–3 cm longo tecto pilis plandulosis, bracteatis foliiformibus. *Sepala* triangularia, 0,4–0,9 cm longa, acuta, tecta pilis glandulosis patentibus, succulenta, viridia. *Petala* oblonga, 1,7–2 cm longa, plerumque acutissima, connata in tubo 1–1,4 cm longo, apicibus recurvis sed erectis in fructu, tecta pilis glandulosis patentibus extus et pilis sparsis tenuibus intus, leviter succulenta, viridia vel flavo-viridia. *Stamina* 1,6–2 cm longa, antheris 0,3–0,5 cm longis, filamentis paene glabris et plerumque flexibus infra antheras. *Squamae* oblongae 0,12–0,15×0,04–0,06 cm, emarginatissimae, succulentae ad basim, flavae. *Carpella* ovariis gracilibus gradate constrictis ad stylos erectos stigmatibus terminalibus; ovarium 30–36 ovulis ovatis sed latioribus ad lateres et papillosis plerumque serialis.

Type: Cape, De Hoop, *H. Hall* 1300 (NBG, holo!).

Perennial shrublet with fleshy stems up to 5 cm in diameter and slightly swollen towards the base, much branched and branches erect and almost fastigiate. *Leaves* alternate, linear-lanceolate, 0,8–3,5 cm long, 0,3–0,5 cm broad, acute, terete or sometimes with a groove on the upper surface, sparsely covered with glandular hairs but becoming glabrous, green or yellowish-green. *Inflorescence* a thyrse with one to several monochasia, with glandular rarely glabrescent peduncle 1,5–3,5 cm long and glandular pedicels 1–3 cm long, with leaf-like bracts. *Sepals* triangular 0,6–0,9 cm long, acute, covered with stout spreading glandular hairs, fleshy, green. *Petals* oblong, 1,7–2 cm long, usually very acute, fused into a tube 1–1,4 cm long, with apices recurved but straightened out again when fruiting, covered with glandular hairs along the outside and in particular the centre of each petal, with scattered fine hairs or rarely papillose on the inside, slightly fleshy, green to yellowish-green. *Stamens* 1,6–2 cm long, with anthers 0,3–0,5 cm long, with filaments almost glabrous and usually with a right-angled outward bend below the anthers. *Squamae* oblong, 0,12–0,15×0,04–0,06 cm, strongly emarginate, succulent towards the base, yellow. *Carpels* with slender ovaries gradually constricted into erect styles and with terminal stigmas; ovary with 30–45 elongate ovules which are usually dumbell-shaped and with papillae often arranged in irregular rows.

This species occurs on rocky slopes in the mountains on either side of the Orange River of Vioolsdrif.

S.W.A.—2717 (Chamaites): near Aiais (–CD), *Pillans 65 8* (BOL). 2816 (Oranjemund): Kahanstal (–BB), *Dinter 8152* (BOL, K, PRE, SAM); *De Winter & Giess 6360* (PRE).

Cape.—2817 (Vioolsdrif): De Hoop (–AA), *Hall 1300* (NBG); 20 km E. of Eksteenfontein (–CD), *Leistner 3373* (PRE); 32 km S.W. of Vioolsdrif (–CD), *Werger 405* (PRE).

7. **Cotyledon tomentosa** *Harv.* in Fl. Cap. 2: 373 (1862); Schonl. in Rec. Albany Mus. 3: 146 (1915). Type: Cape, between Groot River and Trumpeter's Poort, Zeyher 1085 (S, holo!).

subsp. **tomentosa.**

C. tomentosa Harv. in Fl. Cap. 2: 373 (1862). *C. ladismithiensis* sensu Boom in Succulenta, Amst. (1958) 17; sensu Jacobsen, Handb. Succ.Pl. 1: 284, fig. 278 (1960); Sukk. Lex. 134, T.39, 1 (1970), non V.Poelln.

Shrublets with slender branches, much branched. *Leaves* oblanceolate 1,5–2,5 (–3,5) cm long, 0,8–1,4 (–1,7) cm broad, with 3–5 (–10) apical teeth, more or less dorsiventrally compressed.

C. tomentosa is a little known species, which is poorly represented in herbaria and at known localities one finds only a few plants. However, the main obstacle in interpreting the identity of *C. tomentosa* was that Harvey did not mention in his description the three distinct teeth at the apex of the leaves. The type locality given by Zeyher was rather vague, but it must be sought somewhere east of Steytlerville, which lies on the Gamtoos River (alias Groot River). The plant was recently collected in the mountains just north of Steytlerville (*Tölken* 1778).

Then *C. heterophylla* Schoenl. non Roxb. was described from the vicinity of Ladismith, but being a later homomym it must be replaced by the name *C. ladismithiensis* V.Poelln. The latter taxon is here considered to be a separate subspecies of *C. tomentosa*, which is distinguished from the typical subspecies by its longer almost terete leaves as described below. The number of teeth on the leaves varies greatly on the same and different plants, and juvenile plants of both subspecies seem to have leaves with 1–3 teeth. The leaves of juvenile plants and of plants of the subsp. *tomentosa* growing in deep shade are villose, while those of the subsp. *ladismithiensis* are tomentose, but no seedlings have been seen.

Subsp. *tomentosa* has been recorded from near Calitzdorp, Willowmore and Steytlerville, where it occurs on the slopes of sheltered kloofs. Plants of the subsp. *ladismithiensis* occur on rock outcrops between Laingsburg and the northern slopes of the Langeberg near Muiskraal.

subsp. **ladismithiensis** (*V.Poelln.*) *Toelken*, comb. nov. et stat. nov.

C.ladismithiensis V. Poelln. in Jahrb. Deutsch.Kakt. Ges. 1: 94 (1936); in Fedde Repert. 42: 40 (1937). Type: Cape, between Ladismith and Laingsburg, *E.Pillans* sub N.S. Pillans 968 (GRA, holo!; BOL). *C. heterophylla* Schoenl. in Rec. Albany Mus. 2: 150 (1907), non Roxb. (1814); in Rec. Albany Mus. 3: 146 (1915). Type: same as for *C.ladismithiensis*.

Shrublet with rigid spreading branches, little branched. *Leaves* oblong-elliptic (3–) 3,5–5,5 (–8) cm long, 0,8–1,2 cm broad, with 1 (–3) apical teeth, usually almost terete and only occasionally the upper surface is compressed.

CAPE.—2033 (Montagu): Anysberg (–DB), *Stokoe 8708* (BOL); western Touwsberg (–DB), *Wurts 1467* (NBG). 2133 (Ladismith): Ladismith (–AD), Joubert s.n. (BOL); Huisrivierpas (–BC), *Marloth 13128* (PRE); Ockertskraal (–CA), *Hall 1224* (NBG); 16 km S. of Ockertskraal (–CA), *Tölken 1699* (BOL); Adamskraal (–CC), *Muir sub BOL 30962;* Muiskraal (–CC), *Muir sub Marloth 12185* (PRE); between Laingsburg and Ladismith, *E. Pillans sub N.S. Pillans 968* (BOL, GRA).

UITTREKSEL

Vyf nuwe species en een variëteit word beskryf en die nuwe kombinasie Cotyledon tomentosa *Harv. subsp.* **ladismithiensis** (*V.Poelln.*) *Toelken word teweeggebring. Die volgende nuwe name is gepubliseer:* C. **sulphurea** *Toelken*, C. **occultans** *Toelken*, C. **similis** *Toelken*, C. **viridiflorum** *Toelken*, C. **hallii** *Toelken en* C. pygmaea *Barker var.* **tenuis** *Toelken.*

Bothalia 12,2: 195–197 (1977)

The identity of *Erica flavisepala*

E. G. H. OLIVER*

ABSTRACT

The recording of a few scattered plants of *E. flavisepala* Guth. & Bol. among sympatric populations of two other species led to a comparison of their morphological characters. From this comparison a putative hybrid origin was indicated, thus *E.* × *flavisepala* Guth. & Bol.=*E. thunbergii* Montin × *E. sphaerocephala* Wendl.

RESUME

*L'IDENTITE D'*ERICA FLAVISEPALA

*L'observation de quelques plants d'*E.flavisepala *Guth. & Bol., dispersés parmi des populations sympatriques de deux autres espèces, a conduit à une comparison de leurs caractères morphologiques. Cette comparaison suggère une origine hybride, vraisemblablement* E. × flavisepala *Guth. & Bol.* = E. thunbergii *Montin* × E. sphaerocephala *Wendl.*

In Flora Capensis (1905) Guthrie and Bolus described *E. flavisepala* from material that had been sent to them in a consignment of *E. thunbergii* Montin from an unspecified locality in the Cold Bokkeveld. The species were reported as growing together.

The authors stated that their material was difficult to place satisfactorily in any of the sections of the genus and that it constituted a well-marked species with a general aspect strikingly similar to that of *E. thunbergii*. But they noted that it did not have the peculiar globose corolla-tube of *E. thunbergii* and, although anomalous, placed it in the same section, *Cyatholoma*.

Since the original collection of *E. flavisepala* no material has been collected until recently. Mr G. Kirsten, a keen collector of ericas, while examining populations of *E. thunbergii* in the Loch Lynne area of the Cold Bokkeveld, came across a few isolated plants which I was able to confirm were *E. flavisepala*. I decided to visit the area myself to study the species in the wild.

The fine populations of *E. thunbergii* were located without any difficulty in the Hartebeeskloof growing in seepage zones on south-facing slopes being clearly visible from a distance. Growing in the same seepage zones were groups of the pink-flowered *E. sphaeroce-*

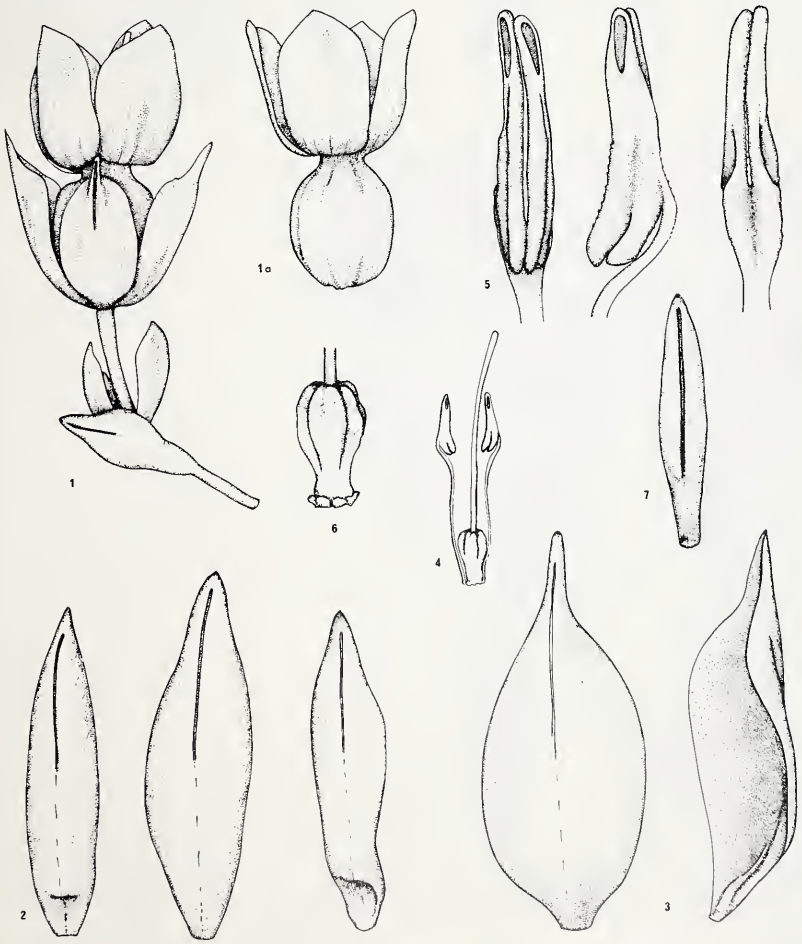


Fig. 1.—*Erica thunbergii*. 1, flower, ×5; 1a, corolla, ×5; 2, bracteoles, ×10; 3, sepals, ×10; 4, androecium and gynoecium, ×5; 5, anther, front, side and back views, ×20; 6, ovary, ×10; 7, leaf, ×10 (from *Oliver* 5139).

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

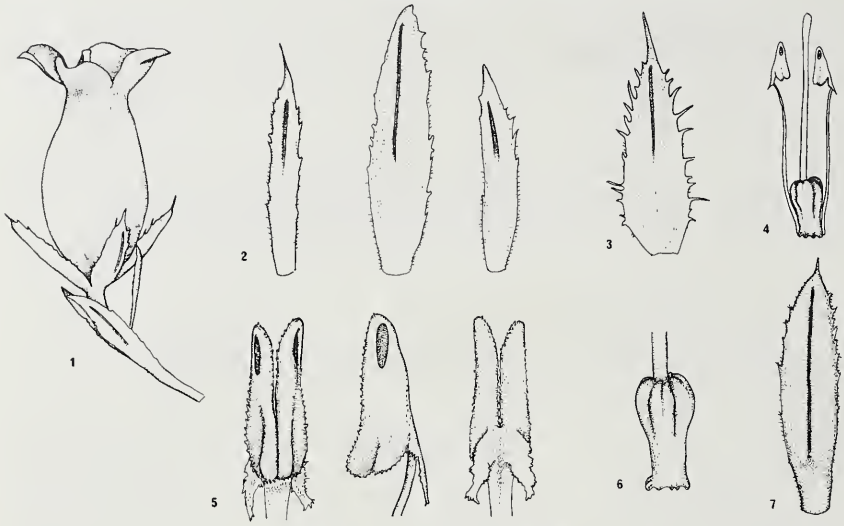


Fig. 2.—*Erica*×*flavisepala*. 1, flower, ×5; 2, bracteoles, ×10; 3, sepal, ×10; 4, androecium and gynoecium, ×5; 5, anther, front, side and back views, ×20, 6, ovary, ×10; 7, leaf, ×10. (from *Oliver* 5140).

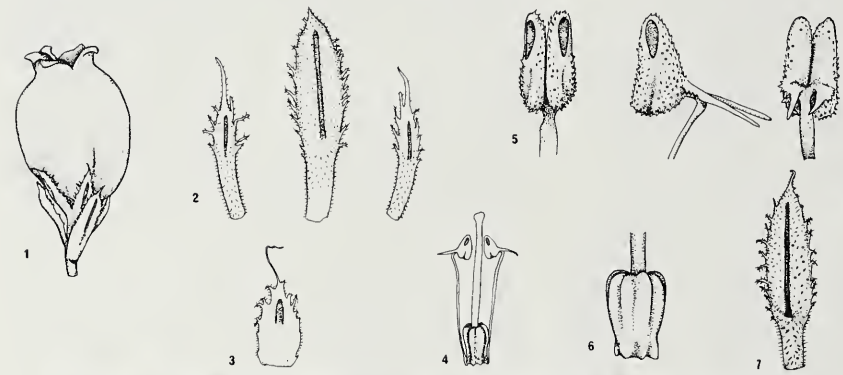


Fig. 3.—*Erica sphaerocephala* 1, flower, ×5; 2, bracteoles, ×10; 3, sepal, ×10; 4, androecium and gynoecium, ×5; 5, anther, front, side and back views, ×20; 6, ovary, ×10; 7, leaf, ×10. (from *Oliver* 5141).



Fig. 4.—Branches of 1, *Erica sphaerocephala* (*Oliver* 5141); 2, *Erica*×*flavisepala* (*Oliver* 5140); 3, *Erica thunbergii* (*Oliver* 5139)

TABLE 1.—Comparison of morphological characters of *E. thunbergii*, *E.* × *flavisepala* and *E. sphaerocephala*

	E. thunbergii	*E.* × *flavisepala*	*E. sphaerocephala*
Branches....	Glabrous	Puberulous to glabrescent	Puberulous with longer plumose cilia in between
Leaves.....	3-nate Glabrous Not ciliate Up to 7 mm long	4-nate to scattered Glabrous, rarely sparsely puberulous Shortly plumose ciliate Up to 4 mm long	4-nate to scattered Puberulous Plumose ciliate Up to 4 mm long
Flowers.....	1–3-nate on ends of short lateral branchlets aggregated towards ends of main branches	2–9-nate on ends of short lateral branchlets or main branches, sometimes aggregated	Capitate heads of 6–23 flowers on ends of main or short lateral branchlets
Pedicels.....	9–12 mm long glabrous Glabrous	3–5 mm long Glabrous to very sparsely puberulous	1–2 mm long Sparsely puberulous.
Bracteoles...	5–6 mm long Canary-yellow Glabrous Not ciliate	3–4 mm long Yellow tinged red Glabrous Shortly plumose ciliate	1,5–3 mm long Green to reddish Puberulous Plumose ciliate
Calyx.....	5–7 mm long Canary-yellow Glabrous Not ciliate Carinate, cucullate	2,5–3 mm long Yellow tinged red Glabrous to sparsely puberulous Shortly plumose ciliate Very slight carinate	1–1,5 mm long Green to reddish Glabrous to sparsely puberulous Plumose ciliate Flat
Corolla.....	9–10 mm long Globose tube, constricted neck and large spreading lobes Tube white, lobes orange-red	7–8 mm long Urceolate with small slight spreading lobes Tube and lobes pinkish red	5–6 mm long Globose-urceolate to obovoid-urceolate with small slightly spreading lobes Tube and lobes pink
Anthers....	2,0–2,1 mm long Prognathous at the base Muticous	1,2–1,3 mm long Semi-prognathous Aristate	0,7–0,8 mm long Not prognathous Long aristate
Ovary.....	Stipitate	Stipitate	Sessile

phala. While investigating *E. thunbergii*, a few plants of *E. flavisepala* were found. It was immediately suspected that these few scattered plants were hybrids between the frequently occurring *E. thunbergii* and *E. sphaerocephala*.

E. thunbergii (Fig. 1) is a very distinct species with yellow, orange and white flowers with globose corolla-tubes. It belongs to the section *Cyatholoma*, which it shares with *E. corydalis* Salisb. and *E. flavisepala* (Fig. 2), the characteristic feature being the globose corolla-tube with a large dilated cup-shaped limb. *E. corydalis* with flowers all white, is also a very distinct species occurring in the coastal mountains of the Caledon district. *E. sphaerocephala* (Fig. 3) belongs to a completely different section, *Pseuderemia*, which is characterized by having the flowers arranged in a many-flowered capitate head. (See Fig. 4).

A comparison of morphological characters of my three collections, *Oliver* 5139, 5140 and 5141 which are illustrated in the accompanying figures, clearly shows the intermediate nature of *E. flavisepala*. The basic shapes and sizes of the bracteoles, pedicel, sepals, corolla, anthers and ovary of the two parent species are very distinct, while those of *E. flavisepala* are intermediate in most respects.

E. thunbergii is almost entirely glabrous except for a few hairs very occasionally found on the petioles, whereas in *E. sphaerocephala* the branches, leaves, pedicels, bracteoles and sepals are all puberulous and ciliate, the cilia being plumose. The anthers of *E. thunbergii* are distinctly prognathous and are distinctly aristate. The ovary in *E. thunbergii* is stipitate and in *E. sphaerocephala* it is sessile.

The flower colours are very distinctive. In *E. thunbergii* the large bracteoles and sepals are bright canary-yellow, the corolla-tube white and the lobes brillian orange-red. In *E. sphaerocephala* the bracteoles and sepals, which are relatively small, are green to reddish in colour and the corolla is pink. In *E. flavisepala* the bracteoles and sepals are yellow tinged with red and the corolla is bright pinkish red.

The pollen of *E. thunbergii* and *E. sphaerocephala* is typical of the genus *Erica*, namely in tetrads. The pollen of the collection *Oliver* 5140 is abnormal in consisting of an equal quantity of tetrads and single grains mixed with some shrivelled grains. This supports the view of the hybrid nature of *E. flavisepala*.

The occurrence of only a few scattered plants of *E. flavisepala* amongst the populations of the other two species indicates that the plants were a chance cross that is not reproductively established. Unfortunately it has not been possible to study the chromosomes. The few species of *Erica* which have so far been investigated all have n=12 and their chromosomes are extremely small. It is therefore unlikely that taxonomically useful information could be derived from a brief investigation of the three taxa.

The facts as set out (in Table 1) indicate the putative origin of *E. flavisepala* Guth. & Bol. (*E.* × *flavisepala* Guth. & Bol.=*E. thunbergii* Montin × *E. sphaerocephala* Wendl.).

UITTREKSEL

Die vermelding van 'n paar verspreide plante van E. flavisepala *Guth. & Bol. tussen simpatriese populasies van twee ander soorte het gelei tot 'n vergelyking van hul morfologiese eienskappe. Uit hierdie vergelyking kan 'n veronderstelde hibridiese oorsprong aangedui word, dus* E. × flavisepala *Guth. & Bol.*=E. thunbergii *Montin* × E sphaerocephala *Wendl.*

Bothalia 12,2: 199–203 (1977)

The identity of *Eriosema nanum*

C. H. STIRTON*

ABSTRACT

An examination of available evidence leads to the conclusion that *Eriosema nanum* Burtt Davy must be regarded as a synonym of *E. ellipticifolium* Schinz. The relationship between *E. ellipticifolium* and *E. uniflorum* Burtt Davy is discussed.

RESUME

*L'IDENTITE D'*ERIOSEMA NANUM

Eriosema nanum *Burtt Davy doit être considéré comme un synonyme d'*E.ellipticifolium *Schinz. A cette conclusion basée sur l'examen des preuves disponibles est jointe une discussion de la relation entre* E.ellipticifolium *et* E.uniflorum *Burtt Davy.*

INTRODUCTION

Eriosema nanum Burtt Davy, together with *E. populifolium* Harv. and *E. angustifolium* Harv., are among the rarest of the Fabaceae in South Africa. Recent intensive field studies of *Eriosema* (Stirton, 1975) showed the widespread occurrence of hybridization and of morphological variation in the genus in South Africa. This paper assesses various aspects of phenotypic plasticity and interspecific hybridization as they affect the identity and delimitation of *E. nanum*.

HISTORY

Schinz, in Vjschr. Naturf. Ges. Zürich 66: 229, 1921, based *E. ellipticifolium* on *Junod* 1411 from Shilouvane and *Junod* 2534 (Fig. 1) from Marovunge, both in the Eastern Transvaal. Owing to the absence of ripe or almost ripe fruits, he was unable to establish clearly whether he was dealing with a *Rhynchosia* or an *Eriosema* species ("Solange keine reifen oder nahezu reifen Früchte vorliegen, ist es vorlaufig ein aussichtsloses Bemühen, feststellen zu wollen, ob es sich um eine *Rhynchosia*—oder eine *Eriosema*-Art handelt, sicher ist, dass sie sich mit keiner der mir bekannten Arten dieser oder jener Gattung deckt"). He commented, however, that the plant was reminiscent of *E. salignum*, but differed in its lower surface indumentum. The name *E. ellipticifolium* has never been taken up.

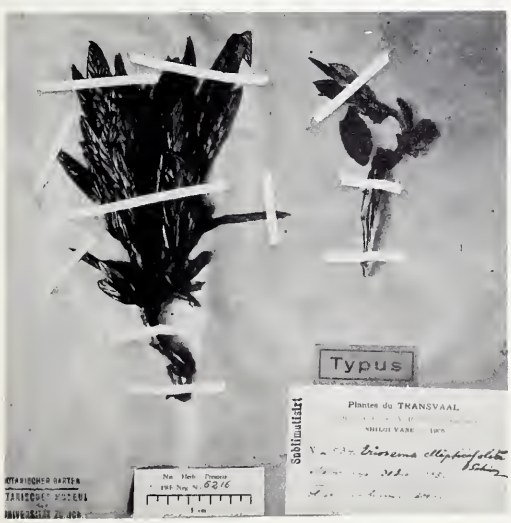


FIG. 1.—*Junod* 2534, lectotype of *Eriosema ellipticifolium*.

In 1932 Burtt Davy treated *E. ellipticifolium* very briefly under the heading "species not seen". In this work, however, he published *Eriosema nanum* based on *Galpin* 1139 from the summit of the Saddleback Mountain in the Barberton area (Fig. 2). As its allies he noted *E. rufescens* Schinz and *E. burkei* Benth. and commented also that it was perhaps closest to *E. uniflorum* Burtt Davy.



FIG. 2—*Galpin* 1139, isotype of *Eriosema nanum*.

A study of type specimens leaves no doubt that *E. nanum* is synonymous with *E. ellipticifolium*. Population studies showed that the wide leaf variation encountered is the result of a cline of decreasing width in a northerly direction (Stirton, 1975). The type localities of *E. ellipticifolium* occur in the northern extremities of this range. It is unfortunate that the more descriptive name *nanum* must be superseded.

*Botanical Research Institute, Department of Agricultural Technical Services. Private Bag X101, Pretoria.

FIELD OBSERVATIONS

Plants growing in full sun tended to be shorter and more compact than plants of the same species found growing under different intensities of shade. In Fig. 3 plants of *E. ellipticifolium* that were found growing in short open grassland (plant 1) are contrasted with those growing along a road bank in a pine forest (plant 2). Plant 1 can be seen to be smaller and more compact than plant 2. Other obvious differences, not all observable from the photographs, are the longer inflorescences, the thinner leaves and the less prominent secondary and tertiary venation in plant 2. Plants that grew through a thick canopy of grass had the same facies as the plants that grew in or along forest margins. These features can be clearly seen on *Stirton* 1431. These various expressions of morphological form could possibly be the result of a competition balance of mineral nutrients, degree of light intensity, extent of water availability, or a combination of these and other factors. The plants shown in Fig. 3 were chosen as representative of the range of variation within the species after a critical inspection of their populations.



FIG. 3—*Eriosema ellipticifolium*. The different facies of plants growing: 1, in short open grassland (*Stirton* 1467); 2, on a roadbank in a pine forest (*Stirton* 1486); 3, in burnt veld (*Stirton* 1040); 4, in unburnt veld adjacent to 3 (*Stirton* 1041).

Plants that grew in burnt veld (Fig. 3: 3) had a more stunted form than plants of the same species which grew in adjacent unburnt veld (Fig. 3: 4). These plants were collected on the same day. The various populations were observed subsequently and it was found that once the new grass had come away the "dwarf plants" began to grow lank so that by the end of the season they were similar, but still shorter, than plants collected in the adjacent tall unburnt grassveld. The plants that grew in the burnt veld had almost completed their flowering period by the time the plants which grew in the unburnt veld had begun to flower.

The observations in open veld and in forest, and in burnt and unburnt veld, were found to be consistent throughout the range of distribution of *E. ellipticifolium*. The results lead me to suspect that once the type specimen of *E. uniflorum* Burtt Davy is compared, it will probably have a facies similar to plant 2 in Fig. 3 and hence synonymous with *E. ellipticifolium*.

Compton (1974, pers. comm.) has indicated that he intends to incorporate *E. uniflorum* under *E. nanum* in his revised Flora of Swaziland. Judgement is here reserved until the type is traced, since the description of *E. uniflorum* has features linking *E. ellipticifolium* and *Stirton* 1482 (*E.* sp. nov.) allied to *E. cordatum*. On the *Galpin* 1139 sheet from the Bolus Herbarium there is a specimen *Bolus* 11854 that has three Bolus manuscript names; *uniflorum, pumilum* and *cryptantha*. Appended to the specimen is a note, apparently in N. E. Brown's handwriting, that says "We afterwards decided that this was probably a stunted form of *E. burkei*". The specimen is *E. ellipticifolium*. Field studies (Stirton, 1975), however, indicated that stunted forms of *E. pauciflorum* Klotzsch, rather than *E. burkei*, are deceptively similar to *E. ellipticifolium*.

The most noticeable variation observed in the field was the range in number of flowers per inflorescence. Plants of the same population were found to have inflorescences bearing from one to ten flowers.

Although most specimens have been reasonably easy to place in this species there remain a few problems. Hybridization cannot be ruled out as the cause of some complexing difficulties encountered in a recent field trip. Two populations in particular require a detailed study as in both areas *E. ellipticifolium* grows sympatrically with the rare *E. angustifolium* Burtt Davy and an undescribed taxon. A feature of these populations is their marked geographical separation viz. Magoebaskloof (N. Transvaal) and Havelock (Swaziland) and also the wide range of "intermedates" found. Flower colour, pubescence and the shape of stipules have been shown in preliminary hybridization studies (Stirton, 1975) on other species to be reliable indicators of putative hybrids. These three characters varied markedly in "intermediate" plants in both populations. *E. angustifolium* has a striking, stiff, rufous, patent indumentum, linear leaves, erect habit, and yellow flowers, and is not readily confused with either *E. ellipticifolium* or *Stirton* 1445 (*E.* sp.) The latter occurs from the N. Transvaal southwards to Swaziland and although fairly common in isolated areas has not been previously collected. This multi-stemmed plant is a pink and yellow flowered perennial with prostrate habit, and small unifoliolate leaves. Its closest affinity is *E. ellipticifolium*. The intermediate plants at Magoebaskloof seem to be hybrids between *E. angustifolium* and *E. ellipticifolium* (*Stirton* 1442), and between *Stirton* 1445 (*E.* sp.) and *E. ellipticifolium* (*Stirton* 1446). Further field studies are necessary before all three putative parents are clearly delimited. The inter-relationships of these three species remain obscure.

Three specimens named *E. ellipticifolium* in this study are doubtful: these are *Jacobsen* 1587, *Coetzer* 150, and *Vahrmeijer* 2433. The last two of these, although very close to *E. ellipticifolium*, differ in pubescence and their very acute leaves. All these will no doubt be easier to place once all the montane species of *Eriosema* have been studied.

E. ellipticifolium begins flowering in early September and reaches a peak in December, occasionally extending into January. The Natal populations flower much earlier than those in the Transvaal.

TAXONOMY

Eriosema ellipticifolium *Schinz* in Vjschr. Naturf. Ges. Zürich 66: 229 (1921). Syntypes: Transvaal, Shilouvane, near Sanatorium, *Junod* 1411 (Z!); Marouvunge, *Junod* 2534 (Z!). Lectotype: *Junod* 2534 (Z!).

Eriosema nanum Burtt Davy, Fl. Transv., 2: XXII (1932); Ross, Fl. Natal 208 (1972). Type: Transvaal, Saddleback Mountain, *Galpin* 1139 (PRE, holo.!; BOL, NBG, NH).



FIG. 4.—*Eriosema ellipticifolium*. 1, habit, 1: 2, perennial rootstock, x 1; 3, flower bract, x 7½; 4, flower, x 2¼; 5 calyx opened out, x 7½; 6a, standard opened out x 5¼; 6b, standard closed, x 5¼; 7, wing, x 5¼; 8, keel, x 5¼; 9, vexillar stamen, x 7½; 10, staminal sheath, x 7½; 11, discoid floral nectary, x 15; 12, gynoecium, x 7½; 13, stigma, x 33; 14, fruit pod, x 1; 15a, seed with strophiole, face view, x 5¼; 15b, seed with strophiole, marginal view showing hilum, x 5¼.

Perennial herb (4) 9–12 (25) cm high with one to six stems from short stylopodium of carrot-like, usually constricted, underground rootstock. *Stems* erect or ascending, 3–10 (23) cm long; terete or angular, often ribbed, glandular or eglandular, clothed with short white pubescent and long spreading pale yellow or white, hairs. *Stipules* free, 6–15 mm long, 2,0–3,5 mm wide; narrowly ovate to ovate, often falcate, striate, white or ferruginous hairy. *Leaves* trifoliolate, basal leaves unifoliolate; leaflets 4,0–7,0 cm long, 1,4–3,5 cm wide, laterals smaller, elliptic to narrowly elliptic or narrowly oblong, base truncate, mucronate, middle nerve slightly sunken above, prominent and subreticulate below, short appressed pubescent on both sides, denser on nerves, densely orange gland-dotted below, lightly above, terminal leaflet symmetrical, laterals asymmetrical with bases slightly oblique; young leaves glandular, long appressed tawny haired on veins with short curly dense pubescence between; *Petiole* 4–11 mm long; *Petiolules* ca. 2 mm long; rachis 5–8 mm long. *Racemes* 1–10-flowered; peduncle (1,0) 2,0–3,5 (7,5) cm long, canaliculate, with long spreading tawny, or long white hairs interspersed with short white deflexed hairs; rachis 0,7–2,1 cm long; pedicels ca. 3 mm long. *Flowers* 6–10 (13) mm long, 3–5 mm wide, reflexed, corolla barely exceeding calyx, yellow; *bracts* 6–8 mm long, 1,0–1,5 mm wide, lanceolate, shallow boat-shaped, 3–6-veined, thinly pilose, more than half length of flower. *Calyx* 6–9 mm long with long and short admixed pale yellow or white hairs, glandular outside, hairy inside at apex of lobes with smaller hairs scattered on either side of veins; tube 2,0–2,5 mm long, slightly longer between horn lobes; lobes unequal, lanceolate, 3–4 times longer than tube, horn lobes 7,5–8,0 mm long curving inwards, lateral lobes 7,0–8,0 mm long curving upwards; keel lobe longest, 8,0–9,2 mm long. *Standard* yellow (7,5) 9–10 (13,0) mm long, (4,5) 6,0–7,0 mm wide, narrowly obovate, often narrowed towards base, white pubescent and glandular on back; claw 2,0–2,6 mm long; width between auricles 3,0–4,0 mm; appendages free of auricles, being upcurled flaps joined slightly in the middle, (1,5) 3,5–4,0 mm from base of claw. *Wings* 7,5–10,1 mm long, 2,0–3,3 mm wide at maximum, longer than keel blades, eglandular, occasionally very glandular; claw 1,5–2,5 mm long, attenuate; auricle (1,2) 1,5–1,6 mm high, straight. *Keel blades* 6,5–7,5 (8,9) mm long, 3,0–4,0 (4,6) mm wide at maximum, auricle 1,0–1,7 (2,0) mm high, claw 1,7–3,0 mm long, attenuate, apex rostrate. *Staminal sheath* 5,7–7,0 mm long, 2,7–4,0 mm wide at maximum, free stamen 5,0–6,0 mm long, basal knee 1,0–1,3 mm long. *Gynoecium* 6,0–6,6 mm long; ovary 2,4–3,0 mm long, subsessile; clothed with long stiff hairs as far as point of style swelling or flexure; gynophore 0,1–0,5 mm; style unevenly thickened, widest at middle of thickening, curvature 2,0–2,2 (2,7) mm high; stigma globose, inserted. *Nectary* 0,4–0,5 mm high, discoid, margin erose. *Fruits* broadly ovate, 1,4–1,6 cm long, 0,9–1,0 cm wide, clothed with appressed light yellow hairs, denser along sutures, with small stiff hairs between; seeds 0,5–0,6 cm long, 0,3 cm wide, black, or greenish yellow with small faint reddish blotches. (Fig. 4).

Eriosema ellipticifolium is restricted to isolated mountain "islands" in Swaziland, the Transvaal and Natal (Fig. 5). This species exhibits a disjunct distribution over a wide area and over diverging ecological conditions and veld types. If is found between 1 600–2 500 m growing predominantly amongst rocks in short grassland on dry ridges with a northwest aspect. A number of populations has been located on forest margins and along forest roads at the Witklip, Mariepskop and Woodbush Forest Reserves.

SWAZILAND.—2631 (Mbabane): Mbabane (–AC), *Rogers 11601* (PRE).

TRANSVAAL.—2329 (Pietersburg): Haenertsburg (–DD), *Pott 4798* (PRE). 2330 (Tzaneen): Magoebaskloof Hotel (–CC), *Stirton 1443* (PRE). 2429 (Zebediela): Donkerfkloof near Chuniespoort (–BA), *Vahrmeijer 2443* (PRE). 2430 (Pilgrim's Rest): The Downs (–AA), *Rogers 22057* (PRE); near Reitz's grave on Mariepskop (–DB), *Stirton 1449* (PRE); Ohrigstad Nature Reserve (–DC), *Jacobsen 1587* (PRE). 2530 (Lydenburg) Dullstroom (–AC), *Galpin s.n.* (24–12–1932, BOL); Witklip Forest Station (–BD), *Kluge 195, 626* (PRE); summit of Saddleback Mountain (–CC), *Galpin 1139* (BOL, GRA, NBG, NH, PRE). 2531 (Komatipoort): Havelock Border Post (–CC), *Stirton 1464* (PRE).

NATAL.—2731 (Louwsburg): Mount Inyati (–CC), *Hilliard & Burtt 5889* (NH, NU). 2830 (Dundee): The Kop (–DD), *Stirton 1033, 1040, 1041* (PRE).

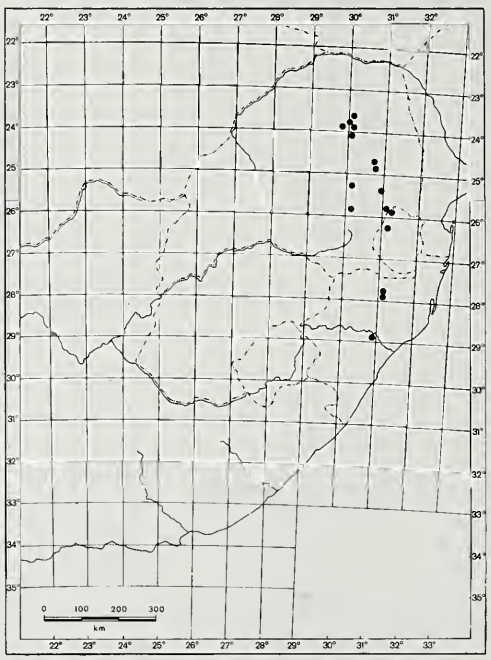


FIG. 5.—*Eriosema ellipticifolium*. Known distribution in Southern Africa.

Junod 2534 is chosen as lectotype, since the quantitative data given in the protologue indicates that Schinz must have based most of his description on the two specimens on this sheet.

This little-known species has proved to be more common and widespread than was previously accepted. The available herbarium material had been placed under no less than six species. It had been most commonly confused with *Eriosema cordatum* var. *cordatum*, but is readily separated from this and all other species by its very long calyx lobes which almost equal the length of the flower.

Despite its widespread distribution (Fig. 5) this species is remarkably uniform and distinctive in the field. Its poor representation in herbaria is probably attributable to its dwarf habit (Fig. 6) and not to its scarcity in the field as, during a recent trip to the eastern Transvaal, it was found to be locally common throughout the moist highlands.



FIG. 6.—*Eriosema ellipticifolium:* dwarf habit.

ACKNOWLEDGEMENTS

This article is an extension of part of a thesis submitted for the M.Sc. degree at the University of Natal, Pietermaritzburg. I am most grateful to Dr. K. D. Gordon-Gray for her guidance and advice during the initial stages of this study and for kindly providing funds for Fig. 4. I am grateful to the Director, Botanisches Museum der Universität Zürich, for the loan of the types of *E. ellipticifolium* Schinz.

UITTREKSEL

'n Ondersoek van al die beskikbare gegewens dui daarop dat Eriosema nanum *Burtt Davy 'n sinoniem van* E. ellipticifolium *Schinz is. Die verwantskappe tussen* E. ellipticifolium *en* E. uniflorum *Burtt Davy word ook bespreek.*

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STIRTON, C. H., 1975. *A contribution to knowledge of the genus* Eriosema *(Leguminosae-Lotoideae) in Southern Africa (excluding Mozambique and Rhodesia).* Unpublished M.Sc. thesis, University of Natal, Pietermaritzburg. 182 pp.

APPENDIX

This appendix lists all specimens considered by the author to belong to *Eriosema ellipticifolium* Schinz:

Bolus 11854 (BOL); *Coetzer* 150 (PRE); *Galpin* s.n. (BOL), 1139 (BOL, GRA, NBG, NH, PRE); *Gilmore* 2284 (PRE); *Hilliard* 2942 (NU); *Hilliard & Burtt* 3358 (NU), 5889, 5908 (NH, NU); *Junod* 1411, 2534 (Z); *Kluge* 195, 626 (PRE); *Muller* 2012 (PRE); *Pott* 4798 (PRE); *Rogers* 1160, 22057 (PRE); *Stirton* 1033, 1040, 1041, 1346, 1431, 1436, 1439, 1441, 1443, 1449, 1464, 1467, 1471, 1474, 1475, 1483, 1486, 1487 (PRE); *Vahrmeijer* 2433 (PRE); *Van der Schijff* 6440 (PRE).

Bothalia 22, 2: 205–208(1977)

Morphological studies of the Ochnaceae*

P. C. V. DU TOIT†

ABSTRACT

The cause of the characteristic sloughing of the bark of certain *Ochna* species is described, while the morphology of the growth buds, leaves and stipules of South African genera of the Ochnaceae is discussed. The taxonomic significance of these features is indicated where relevant.

RESUME

ETUDES MORPHOLOGIQUES SUR LES OCHNACEAE

La cause de la desquamation de l'écorce, caractéristique de certaines espèces du genre Ochna, *est décrite; on discute la morphologie des bourgeons de croissance, des feuilles et des stipules dans les genres sud-africains d'Ochnaceae et, quand il y a lieu, on indique la valeur taxonomique de ces caractères.*

INTRODUCTION

During a recent morphological study of the family Ochnaceae, it was found that relatively little was known of the organography and anatomy of the family. A wealth of taxonomic literature was available, but only a few works gave a synoptic treatment of the anatomy. The aim of this paper is to draw attention to these taxonomically important and interesting characteristics and to stimulate the extrapolation of these finding to other families.

BARK

An interesting characteristic of some of the indigenous species of the Ochnaceae is the rhytidome or outer bark, i.e. all the tissues on the outside of the periderm, that peels off in strips or scales.

According to Esau (1965) this manner of rhytidome formation is common in those species where the phellogen is initiated superficially. While working on the anatomy of the family it was noticed in two species, viz. *Ochna arborea* and *O. pulchra*, that the phellogen was initiated in the epidermis, the epidermal and phellogen cells lying on the same radial lines, but at the same time, it was also initiated quite deep in the cortex. In this instance, the phellogen forms an interrupted undulating band running through the epidermis and cortex right round the stem. In time this undulating band breaks up into outward curving sectors, like shells. These outward curving shells, which overlap and are superimposed over yet others like it, are shed at different times, leaving a smooth, mottled layer of bark (i.e. all the tissues on the outside of the vascular cambium). In these two species it was found that the phellogen gives rise to a very thin layer of phellem, coinciding with the smoothness of the bark when the outer layers slough off (Fig. 1). In all the other indigenous species of the Ochnaceae, the phellogen is initiated relatively deep in the cortex with, in addition, a thick layer of phellem. The outer layers slough away gradually and the bark, exposed after sloughing, is rough and evenly coloured (Fig. 2). Making use of this character the species can be separated into two groups, the one group coinciding exactly with the section Renicarpus to which *O. arborea* and *O. pulchra* belong.

BUDS AND GROWTH PATTERN

Two interesting features regarding the growth pattern of the Ochnaceae were observed that have hitherto escaped notice. The first is the two different kinds of buds encountered, and the second, the growth pattern. The first type of bud found in the family is responsible for the annual growth increment. The growth buds are laterally compressed and taper to a sharp point (Fig. 3). The second type of bud is the flower bud of which two kinds are found. Species where the flowers are borne singly have easily recognizable pear-shaped and globose buds (Fig. 4). Where the flowers are borne in clusters or cymes the buds are produced in a club-shaped structure, similar to the growth buds (Fig. 5).



FIG. 1.—The smooth, peeling bark of *Ochna pulchra*.

* Forms part of a M.Sc. thesis submitted at the University of Pretoria.

† Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.



FIG. 2.—The rough, non-peeling bark of *Ochna holstii*.



FIG. 3.—The laterally compressed growth bud of *Ochna pulchra*.



FIG. 4.—The single flower buds of *Ochna serrulata*.



FIG. 5.—The club-shaped compound flower bud of *Ochna pulchra*.

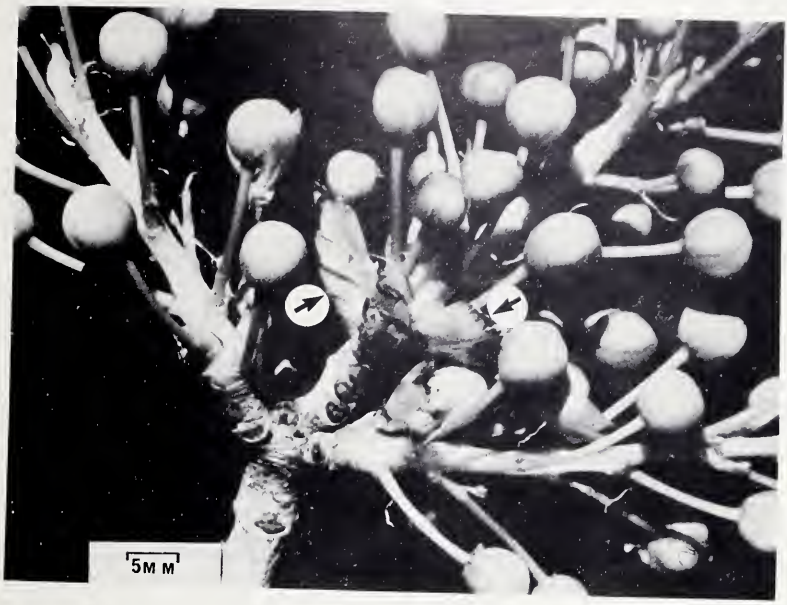


FIG. 6.—The cyme of *Ochna pulchra*; note the two rows of boat-shaped scales.

Both the growth buds and the compound flower buds are protected by a series of scales. The scales are arranged in alternating series. One large serrated or entire scale, covering the axillary bud. On the opposite side of the stem, the space between the two margins of the large scale is covered by a lanceolate or subuliform scale, which seems to be homologous to the two stipules of the foliage leaves.

At the end of the growing season, the flower and leaf buds are already fully developed and open (unfold) with the first spring rains of the following season. In both the growth and flowering buds, a typical feature of the Ochnaceae is displayed, viz. the growthflush, which takes place in early spring when the temperature rises and just after the first spring rains. During the growthflush the scales break away in two or three series and the stem and peduncle elongates (Fig. 6). The scales mostly break away in two series due to their pseudo-distichous arrangement. The angle of divergence is approximately 150°, but due to the stem being twisted, the leaves and scales take on the appearance of being distichous. The spirally arranged nature of the leaves can be seen when the young leaves unfold. During the growthflush, which lasts for approximately a week, the annual growth increment of the plant is completed and the axillary buds of most species are quiescent for the rest of the growing season. The annual growth increment can be recognized by the amount of new growth between the series of scale scars at the tip of the previous season's stems and the growth bud. The quiescent axillary buds in the series of scale scars give rise to the flower buds and/or sideshoots of the following season. In some species stems may also be terminated by flowers.

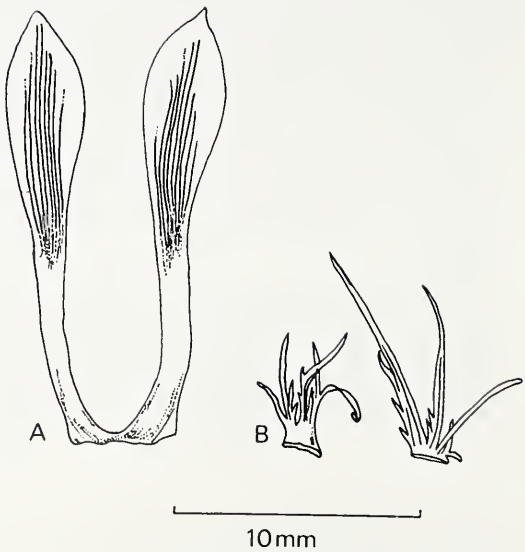


FIG. 7.—Diagram to illustrate the stipules of A, *Ochna* and B, *Brackenridgea*.

LEAVES AND STIPULES

The family Ochnaceae in Southern Africa is represented by two genera, viz. *Ochna* and *Brackenridgea*. In distinguishing between these two major taxa, the morphology of the leaves and stipules was found to be taxonomically useful. According to

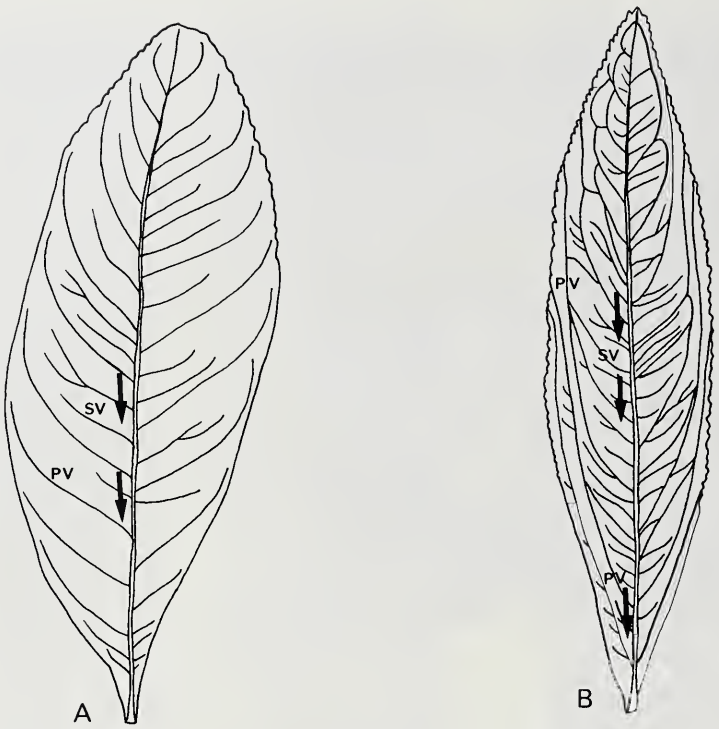


FIG. 8.—Diagram to illustrate the types of veins in A, *Ochna* and B, *Brackenridgea*. PV—Primary-vein; SV—Secondary-vein. Arrows point to the angle of emergence of the different veins.

Sinnott and Bailey (1914), there is a relationship between the occurrence of stipules and the dentations on the leaf margins. In the indigenous species of the Ochnaceae, the leaf margin is excurrent onto the adaxial side of the petiole and joined to the stipules. In these instances the stipules can then be regarded as the most basally situated teeth of the leaf margin.

In all the species of *Ochna* the stipules are caducous, especially in *Ochna pulchra*, in which the stipules are shed just after the growthflush and the teeth of the leaf margin are deciduous with age. The stipules are lanceolate to spathulate, undivided and entire (Fig. 7A). The stipules of *Brackenridgea* remain on the plant for the whole growing season, and are divided into a number of linear lobes, which may be entire or dentate (Fig. 7B).

The venation is a useful taxonomic character and the veins can be divided into primary and secondary veins (Fig. 8). The primary veins are conspicuously prominent on the adaxial surface, with the secondary veins less so. In the case of most of the *Ochna* species both the primary and secondary veins arise from the midrib at an angle of 60°–70°. The veins run parallel to one another with the secondary veins gradually lessening in diameter until they disappear. The primary veins run to the leaf margin, turning distally with their diameter gradually lessening (Fig. 8A). In the case of *Brackenridgea arenaria* and *O. confusa*, the primary veins arise from the midrib, at an angle of 30°–40°, with the primary veins anastomosing near the distal end of the leaf. The secondary veins arise from the midrib at an angle of 60°–70° and run parallel to one another, gradually lessening in diameter until they end at the primary veins (Fig. 8B).

UITTREKSEL

Die oorsaak van die kenmerkende wyse waarop die bas van sommige Ochna*soorte afdop, asook die morfologie van die groeiknoppe, loofblare en steunblare word bespreek. Die taksonomiese toepaslikheid van die eienskappe word aangedui waar ter sake.*

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Bothalia 12,2: 209—213 (1977)

Leaf anatomy of the South African Danthonieae (Poaceae). I. The genus *Dregeochloa*

R. P. ELLIS*

ABSTRACT

The anatomical structure, of the leaf blade as seen in transverse section, and the abaxial epidermis, of *Dregeochloa pumila* and *D. calviniensis* is described and illustrated. A generic description is included and the relationships of the genus are briefly discussed.

RESUME

ANATOMIE DE LA FEUILLE DES DANTHONIEAE (POACEAE) SUD-AFRICAINES. I. LE GENRE DREGEOCHLOA

La structure anatomique du limbe foliaire vu en coupe transversale, ainsi que l'épiderme abaxial de Dregeochloa pumila *et de* D.calviniensis *sont décrits et illustrés. On y joint une description du genre avec une brève discussion de ses relations.*

INTRODUCTION

The genus *Dregeochloa* Conert was described to accommodate the species *Danthonia pumila* Nees and a newly described species *Dregeochloa calviniensis* Conert (Conert, 1966). These two species have certain distinct characteristics of spikelet morphology, leaf anatomy and especially the structure of the mature caryopsis, which indicates that this genus occupies a unique and somewhat isolated position in the Danthonieae. Plants of the genus were previously assigned to the genus *Danthonia* DC. (Chippindall, 1955), and certain authors (De Wet, 1954, 1956; Jacques-Felix, 1962) have suggested their inclusion in *Asthenatherum* Nevski. However, they can readily be distinguished from both genera by the development of the leaves, the insertion of the central awn and the structure of the caryopsis (Conert, 1966). In addition, these species exhibit characteristic leaf anatomy which tends to confirm their placement together in a separate genus, but throws little light on the phylogenetic position of this genus. In the anatomical descriptions which follow, the following abbreviations will be used:

vb/s—vascular bundle/s
1′vb/s—first order vascular bundle/s
2′vb/s—second order vascular bundle/s
3′vb/s—third order vascular bundle/s
ibs—inner bundle sheath; mestome sheath
obs—outer bundle sheath; parenchyma sheath

ANATOMICAL DESCRIPTION OF THE GENUS *DREGEOCHLOA*

Leaf in transverse section

Leaf outline: U-shaped or canaliculate with two halves of lamina curved upwards to varying degrees on either side of median vascular bundle; forming no angle. Leaves narrow (between 1,60 mm and 3,50 mm wide), proportionately very thick (between 0,30 mm and 0,70 mm). *Ribs and furrows*: adaxial furrows present between all vbs; equally sized, rounded, adaxial ribs present over all vbs irrespective of order. Abaxial ribs and furrows well developed; furrows equal to or deeper than adaxial furrows; ribs in form of flat-topped sclerenchyma caps with horizontal prickles at edges interlocking over cleft-like furrow. *Median vascular bundle*: present; midrib or keel not developed. *Vascular bundle arrangement*: 5 1′vbs in blade; no 2′vbs present; all bundles located nearer abaxial surface. *Vascular bundle structure*: all bundles usually rounded in section although *D. pumila* exhibits a tendency for bundles to be vertically elongated and elliptical; phloem of 1′vbs adjoins inner, thickened sheath; no lysigenous cavity or protoxylem vessels developed; metaxylem vessels extremely narrow (diameter less than adaxial ibs cells), angular and only slightly thickened. *Vascular bundle sheaths*: round in shape in all 3′vbs and most 1′vbs, but in *D. pumila* 1′vb sheaths may be slightly elliptical. Obs always entire with no extensions; comprised of 11–15 cells around 3′vbs and 12–17 cells around 1′vbs; all cells similar in shape, thin-walled and conspicuous but not larger than mesophyll cells. *Sclerenchyma*: abaxial strands well developed in wide, straight, deep bands forming caps on flat abaxial ribs; no sclerenchyma between vbs; fibres thick-walled with lumen narrow; walls stain blue-green with safranin and fast green. *Margin*: sclerenchyma a well developed cap, somewhat pointed; crescent-shaped or fibres may extend abaxially. Sclerenchyma of margin never extends further than directly above and below ultimate vb. Margin without angular prickles. *Mesophyll*: indistinctly radiate; chlorenchyma of elongated, tabular cells relatively loosely and irregularly arranged; air spaces frequent. *Colourless cells*: entirely lacking except for bulliform cells. *Adaxial epidermis*: costal prickle hairs with bases not larger than, and situated between, normal epidermal cells; frequent; hairs slender and elongated, those of *D. pumila* (±0,10 mm) about twice the length of those of *D. calviniensis* (±0,05 mm); no papillae. *Abaxial epidermis:* outer tangential wall of cells flattened or slightly arched; not papillose.

Abaxial epidermis

Intercostal zones: cleft-like, intercostal, abaxial furrows make study and illustration of cells of this zone difficult. *Intercostal long cells:* length slightly greater than width; parallel-sided; moderate undulations of anticlinal walls. *Stomata:* appear low-dome shaped; 1–2 rows on each vertical wall of cleft-like furrow. *Papillae:* absent. *Prickle-hairs:* interlocking prickles present overlying stomatal furrow; single row of prickles on edge of costal zones. *Micro-hairs:* none observed. *Macro-hairs:* absent. *Silica-bodies:* present throughout costal zone; silica cells alternate with costal short cells.

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

ANATOMICAL DESCRIPTIONS OF THE SPECIES

1. Dregeochloa pumila *(Nees) Conert*

Leaf in transverse section

Leaf outline: U-shaped leaves with base and sides about equal in length or more commonly less inrolled with wide, broad base to U. Width from 3,00 mm to 3,45 mm and thickness from 0,63 mm to 0,70 mm in freshly fixed leaves. Dried herbarium specimens narrower (2,00 mm wide) and thinner (0,30 mm thick). *Ribs and furrows:* adaxial furrows very shallow relative to leaf thickness; furrows narrow and cleft-like in sections from dried herbarium material but with broad bases with relatively steep sides in freshly fixed material. Abaxial ribs taller than adaxial ribs; interlocking prickles well-developed and common. *Vascular bundle arrangement:* 1′ vbs separated by single 3′vb except on either side of median vascular bundle where there are two 3′vbs. *Vascular bundle structure:* 3′vb diameter almost same as 1′vbs. *Vascular bundle sheaths:* obs cells rounded or with radial walls straight and tangential walls inflated; translucent, without chloroplasts or with few chloroplasts similar to those of mesophyll. Ibs not distinct around 3′vbs; probably absent; present around 1′vbs; entire, composed of small thickened cells; thickening may be on inner tangential and radial walls or equally on all walls when lumen may become more or less excluded. Adaxial cells of ibs larger than lateral cells; relatively thin walled. *Adaxial sclerenchyma:* small strands developed; shallow sub-epidermal strip or deeper groups of fibres. Strands similar in size over all vbs. *Mesophyll:* indistinctly radiate with chlorenchyma surrounding each individual bundle divided by abaxial furrows and large adaxial bulliform cells. Adaxial chlorenchyma groups narrow and composed of palisade-like cells between adjacent bulliform cell groups. *Adaxial epidermis:* bulliform cells resemble fan-shaped groups with exceptionally large central cell with straight sides occupying more than $\frac{1}{2}$ the leaf thickness. Costal epidermal cells unthickened or with thin cuticle. *Abaxial epidermis:* bulliform cells small, in fan-shaped groups situated at base of furrows; largest bulliform cell not larger than obs cells. Costal epidermal cells with outer wall slightly thickened. Located on sides of adaxial ribs are horizontally projecting prickles with bases not larger than, and situated between normal epidermal cells; barbs thick and relatively very long (0,10 mm), interlocking over furrows.

Abaxial epidermis

Prickles: short, hook-like base; barb long ($\pm$0,10 mm); barb developed from apex of base; barbs lie at right-angles across abaxial furrows. *Silica bodies:* Round, circular to oblong in shape; sometimes shortly dumb-bell shaped with a wide middle portion (Fig. 8).

Specimens examined

S.W.A.—2615 (Luderitz): 1,6 km south of Luderitz lagoon (-CA), *Giess & van Vuuren 653.* 2715 (Bogenfels): Pomona (-AB), *Dinter 4018.*

Cape.—2816 (Oranjemund): 2 km west of Beauvallon on road to Alexander Bay (-DA), *Ellis 2173, 2174:* 9 km west of Beauvallon, *Tölken 5278.*

Discussion

D. pumila is a short (3–10 cm tall), tufted perennial, often forming small, dense, flat cushions up to 15 cm in diameter. It grows in crevices or in loose sand amongst shale-like, schist rocks in a region of extremely low winter rainfall ($\pm$50,0 mm), but where heavy sea mists occur frequently. It appears to be restricted to the coastal belt, less than 15 km from the sea, from just south of the Orange River mouth to the Luderitz area in South West Africa (Fig. 13).

This region undoubtedly is a harsh habitat with extremes of temperature, insolation and precipitation. The proximity to the sea has a moderating effect on seasonal temperature range and frequent mists probably offset the lack of rainfall somewhat, but an extremely large diurnal temperature range is to be anticipated on the dark rocks which this plant prefers. However, xerophytic adaptions are not well reflected in the anatomy of the leaf of *D. pumila.* The leaf is not permanently infolded and the usual copious sclerenchyma and thickened cuticle, often correlated with dry localities, is lacking (Figs. 1 and 2). The stomata are, however, restricted to abaxial furrows which are further protected by numerous interlocking prickles. This arrangement must limit excessive water loss to a certain degree. In addition the leaves are very short with a leathery, succulent texture and the plant forms a low, dense cushion. These growth characteristics are commonly found in xerophytes but are exceptional in the Poaceae.

No other members of the Danthonieae are found in the same habitat as *D. pumila* although *Asthenatherum glaucum* (Nees) Nevski and *Merxmuellera rangei* (Pilg) Conert are found in the adjoining sandy areas but they extend further into Namaqualand, the Namib Desert and even the Kalahari in the case of *A. glaucum.* Anatomically these species are easily seperated.

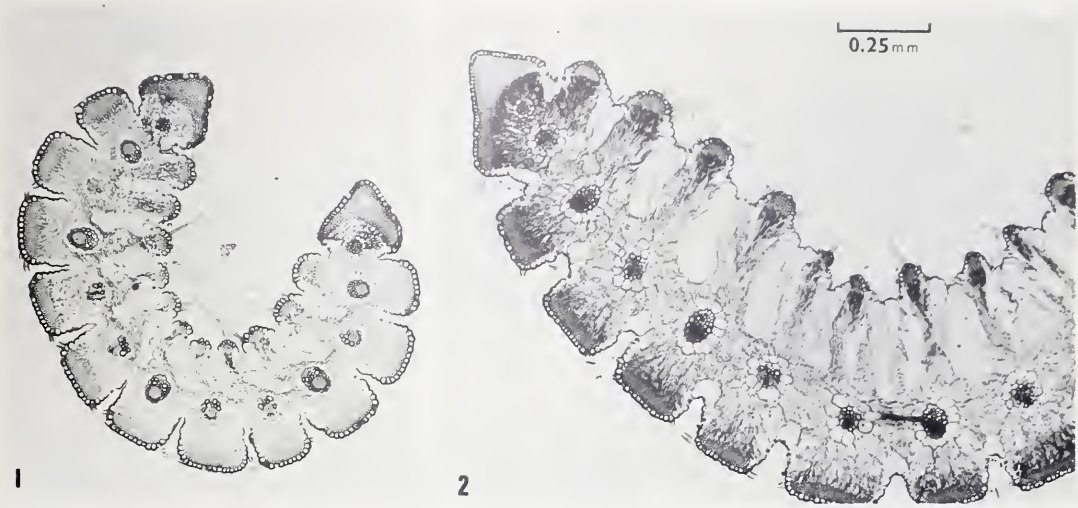
Sections taken from herbarium specimens have a somewhat more xerophytic appearance. The adaxial and abaxial furrows are more narrow and cleft-like and the bulliform cells appear reduced in size. In fact, these specimens superficially resemble *D. calviniensis* sections (of which only herbarium material was studied) more closely than fully turgid, freshly fixed specimens of *D. pumila.* This should serve as a caution when anatomical comparisons are made between sections of herbarium and fresh material. Thus, Dinter 4018 (Fig. 1) resembles the sections of *D. calviniensis* (Figs. 9 and 10) and it is only the sequence of the different orders of vascular bundle and the silica bodies and prickle hairs (Figs. 5 and 6) of the epidermis that reveal it to be a typical *D. pumila* specimen.

Remarkably little variation in leaf anatomy was evident in the specimens studied which may be expected from a species inhabiting a limited area with uniform climate, and occupying such a specialized niche. This species can readily be recognised by the elongated, deep bulliform cells associated with narrow columns of adaxial chlorenchyma cells, the thickness of the leaf and the abaxial furrows with interlocking prickles.

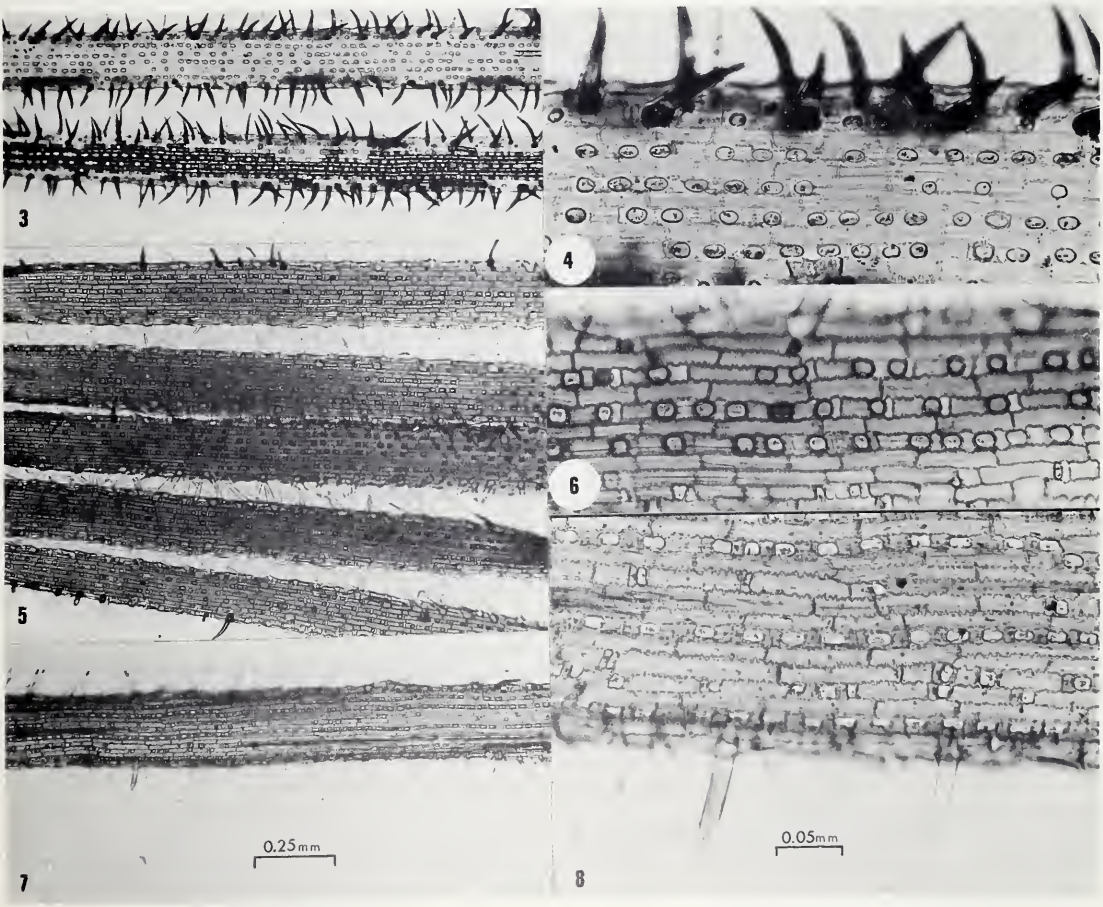
2. Dregeochloa calviniensis *Conert*

Leaf in transverse section

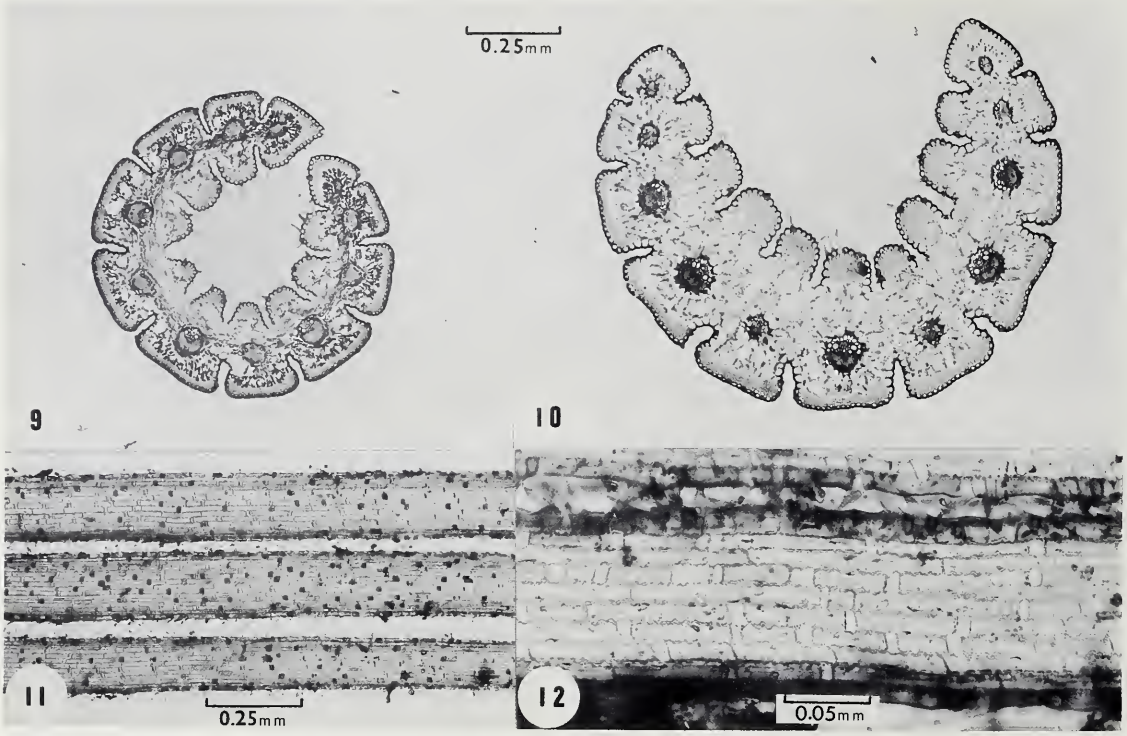
Leaf outline: U-shaped with base and sides equal in length to hollow cylindrical condition where margins almost meet. Generally more tightly inrolled than *D. pumila;* width from 1,60 mm to 2,30 mm in dried material. *Ribs and furrows:* adaxial furrows of medium depth and at least $\frac{1}{4}$ of leaf thickness. (This greater depth may be due to shrinkage in the herbarium material examined). Furrows narrow, cleft-like. Adaxial ribs same height as abaxial ribs although shaped differently; not moniliform; interlocking prickles small and infrequent. *Vascular bundle arrangement:* one 3′vb on either side of the median



FIGS 1 & 2.—*Dregeochloa pumila*: transverse sections of the leaf blade; 1, *Dinter* 4018; 2, *Ellis* 2174.



FIGS 3–8.—*Dregeochloa pumila*: abaxial epidermis; 3 & 4, *Ellis* 2173; 5 & 6, *Dinter* 4018; 7 & 8, *Giess & Van Vuuren* 653.



FIGS 9–12.—*Dregeochloa calviniensis*. 9 & 10, transverse sections of the leaf blade; 11 & 12, abaxial epidermis. 9, *Erasmus* s.n.; 10 11 & 12, *Dekkers* s.n.

vascular bundle; lateral two 1′vbs adjacent to one another with no 3′vbs present between them. *Vascular bundle sheath:* obs cells inflated and rounded; chloroplasts appear specialized and concentrated near inner tangential wall (Figs. 9 and 10). (This observation needs confirmation using freshly fixed material). Ibs well developed and distinct around both 1′ and 3′vbs, complete, composed of small thickened cells often with inner tangential and radial walls markedly thickened. Around 1′vbs the walls of cells adjacent to the phloem very thick with narrow lumen. Adaxial cells of ibs larger than lateral cells of sheath. *Adaxial sclerenchyma:* well developed strand; usually arched following shape of rib; similar over all vascular bundles. *Mesophyll:* indistinctly radiate with the chlorenchyma surrounding each individual bundle being divided by abaxial and adaxial furrows. *Adaxial epidermis:* bulliform cells appear absent, or small and present on sides and bases of furrows (Fig. 10). Costal epidermal cells all with outer wall slightly thickened. *Abaxial epidermis:* bulliform cells absent or only very small; situated on the sides and bases of furrows. Costal epidermal cells with distinct, thick cuticle on outer wall; thickness of cuticle and outer wall being equal to, or greater, than depth of epidermal cell. Interlocking prickles with very short barbs at sides of costal zones.

Abaxial epidermis

Prickles: short, hook-like base; barbs short (±0,05 mm), developed from apex of base; all barbs point irregularly in direction of leaf apex. *Silica-bodies:* Tall and narrow to square; outline smooth, regular (Fig. 12).

Specimens examined

CAPE.—3019 (Loriesfontein): Handelkraal, E.N.E. of Loriesfontein (-CD), *Dekkers s.n.* (PRE, iso). 3022 (Carnarvon): Brandewynskuil, between Vosburg and van Wyksvlei (-DB), *Erasmus s.n.*

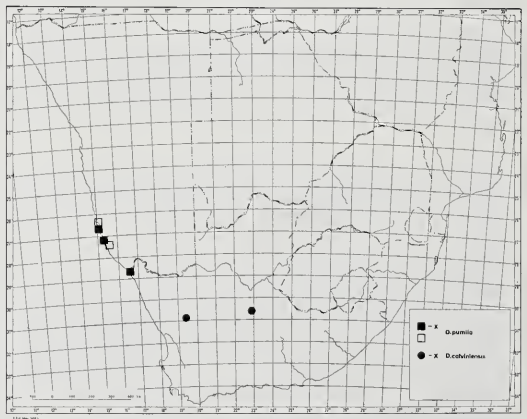


FIG. 13.—Distribution of *Dregeochloa pumila* and *D. calviniensis* compiled from specimens at the National Herbarium, Pretoria (PRE). X indicates localities of specimens studied anatomically.

Discussion

This rare, perennial species is known only from the above two localities and collections. At Handelkraal, on the margin of the Western Mountain Karroo, it is locally frequent on limestone. In contrast to *D. pumila*, this species forms small, dark green, dense and erect tufts from 15–25 cm high.

Vegetatively *D. calviniensis* bears little resemblance to *D. pumila*, but the leaf anatomy is strikingly similar as seen in transverse section. Small differences occur in the shape and size of the bulliform cells (this may have been accentuated by the fact that only herbarium specimens were studied), the size and thickening of the epidermal cells and the prickles and possibly the arrangement of the different orders of

vascular bundles. The abaxial epidermis, however, shows important differences, especially in the shape of the silica bodies. Although *D. calviniensis* has tall and narrow silica bodies (Fig. 12) and *D. pumila* circular or oblong bodies (Figs. 4 and 6), both these shapes, and the fact that the silica cells and short cells are solitary or paired, and not in long rows, are typical festucoid characters (Metcalfe, 1960). This difference, although striking, can thus be expected even in two closely related taxa.

There appears to be a specialization and a centripetal concentration of chloroplasts in the parenchyma sheath cells of both *D. calviniensis* specimens examined (Figs. 9 and 10) and it is unfortunate that no fresh material was obtained to confirm this. In addition, the mesophyll, which is also poorly preserved, appears to consist of two layers of more or less radially arranged chlorenchyma cells. This configuration is typical of the Kranz syndrome but the $^{12}C/^{13}C$ ratios are typical non-Kranz (δ=–26, 32; Dekkers s.n.) as are those for *D. pumila* (δ=–25, 93; de Winter & Giess 6235). The possibility that *D. calviniensis* represents a very early stage in the aquisition (or late stage in the loss) of the Kranz syndrome still exists, and this warrants further investigation. If this is in fact the case then the relationship of *Dregeochloa* to *Asthenatherum*—a Kranz genus in the Danthonieae—becomes much clearer.

DISCUSSION AND CONCLUSIONS

In the past the leaf anatomy of this genus has, to a large extent, been misinterpreted. Thus, de Wet (1954) grouped *D. pumila* with the species now included in the genus *Asthenatherum*—all of which have "chloroplasts localized around the bundles." This, together with morphological criteria, he interpreted as indicating that *D. pumila* belonged to the genus *Asthenatherum*. Jacques-Felix (1962) stated that *D. pumila* had typical panicoid structure and also included this species with *Asthenatherum*. Conert (1962) noted that *D. pumila* did not have elongated radially arranged mesophyll cells. His observations led him to disagree with the above authors and he suggested that *D. pumila* occupied an isolated position in the Danthonieae near *Danthonia*.

In a later paper, de Wet (1960) grouped *D. pumila* with those species where the chlorophyll is not localised around the bundles but uniformly distributed throughout the mesophyll and which possess a thin-walled outer bundle sheath. These new observations led him to postulate that *D. pumila* formed a direct link between *Danthonia* and *Asthenatherum*. He was still of the opinion that in all other respects these two genera resembled one another very closely but Conert (1962) noted that the formation of the callus differed in addition to anatomical differences. This influenced Conert's (1962) proposal of an isolated position for *Dregeochloa* (=*D. pumila*).

Certain epidermal features have also been confused. De Wet (1954) described the silica bodies of *D. pumila* as being spherical and stated that micro-hairs were absent. In the 1960 publication de Wet described the silica bodies as dumbell-shaped and micro-hairs were observed. In the present study no micro-hairs were found but it must be stressed that, in this genus, the intercostal zones are difficult to preserve and study due to the deep adaxial furrows. On all preparations of *D. pumila* the silica bodies are horizontally elongated and oblong in shape although some silica bodies on Giess and van Vuuren 653 (Fig. 8) have indentations in the centre and could be described as being dumbell-shaped.

The observations of this study, based solely on leaf anatomy, confirm that these two species closely resemble one another and constitute a unique, distinct group. Their structure is unique amongst the Danthonieae and they show little anatomical resemblance to any other South African members of this tribe. This supports Conert's (1966; 1971) conclusions that this genus occupies an isolated position within the tribe. However, *Dregeochloa* has certain similarities in common with *Asthenatherum* (abaxial furrows and prickles, spikelet structure and distribution) which may indicate that these two genera had a common ancestor which gave rise to Kranz and non-Kranz groups. The region where these genera occur is a zone where Kranz genera (*Aristida*, *Stipagrostis*, *Eragrostis* etc.) and non-Kranz genera (*Schismus*, *Karoochloa*, *Chaetobromus* and *Merxmuellera*) are equally abundant. *Dregeochloa* shows no anatomical affinities with the genus *Merxmuellera* (=*Danthonia*) and its removal from *Danthonia* appears justified.

ACKNOWLEDGEMENTS

The author is indebted to Miss L. Breytenbach and Miss A. Vermeulen for capable technical assistance and to Dr J. Vogel and Mrs M. Greyling of the Natural Isotopes Division, N.P.R.L., C.S.I.R. for the $^{13}C/^{12}C$ determinations.

UITTREKSEL

Die anatomiese struktuur van die blaar in dwarssnee en die abaxiale epidermis van Dregeochloa pumila *en* D. calviniensis *word beskryf en geïllustreer. 'n Genus beskrywing is ingesluit en die verwantskappe van die genus word kortliks bespreek.*

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Bothalia 12,2: 215–221 (1977)

Cytogenetic studies in the *Eragrostis curvula* Complex

T. B. VORSTER* and H. LIEBENBERG†

ABSTRACT

Cytogenetic studies were undertaken in the *Eragrostis curvula* Complex. Three plants were studied at each of 16 collecting points. The overall morphology and embryo sac development of all plants were evaluated, while the chromosome number and microsporogenesis of some of the plants were also studied. The collecting points were chosen so as to represent a variable environment extending from the bushveld to the highveld regions of the Transvaal. It was found that the embryo sac development of the plants from the bushveld and the highveld were, for all practical purposes, obligate diplosporic apomicts, whereas the transition area contained obligate as well as facultative diplosporic apomicts. The same pattern also held as far as the plant morphology, chromosome number and microsporogenesis were concerned.

RESUME

ETUDES CYTOGENETIQUES DANS LE COMPLEXE ERAGROSTIS CURVULA

Des études cytogénétiques ont été entreprises dans le complexe Eragrostis curvula. *Trois plants ont été étudiés pour chacun des* 17 *points de récolte. La morphologie générale et le développement du sac embryonnaire ont été évalués partout, tandis que le nombre chromosomique et la microsporogenèse de certains plants ont aussi été étudiés. Les points de récolte ont été choisis de manière à représenter un milieu variable s'étendant des steppes boisées ("bushveld") aux prairies de montagnes ("highveld") du Transvaal. On a constaté que, dans les steppes comme dans les prairies, le développement du sac embryonnaire comporte obligatoirement une apomixie diplosporique, pour tout ce qu'on peut en observer; tandis que les zones de transition présentent aussi bien des apomictes diplosporiques obligatoires que des facultatifs. La même distribution s'observe aussi en ce qui concerne la morphologie de la plante, le nombre chromosomique et la microsporogenèse.*

INTRODUCTION

Cytogenetic studies on *E. curvula* (Schrad.) Nees and its close relatives have made it clear that they are probably all part of a large agamic complex. The mechanism of apomixis is diplospory, as defined by Gustafsson (1946), followed by parthenogenesis (Håkansson, 1943) and pseudogamy as the main means of reproduction (Brown and Emery, 1958; Liebenberg, 1961; Liebenberg and Pienaar, 1962; Streetman, 1963; Voight, 1971; Voight and Bashaw, 1972 and Brix, 1974). This is probably the reason why the taxonomy of this complex has been so difficult to unravel.

The *E. curvula* group has a wide distribution throughout Southern Africa and the existence of polymorphism within species and intermediate types between species led De Winter (1955) to treat *E. robusta* Stent as a synonym of *E. curvula* and to maintain *E. chloromelas* Steud. as a closely related species in what is generally known as the *E. curvula* Complex.

Unfortunately most of the cytogenetic studies undertaken on *E. curvula* and its relatives have been carried out, for understandable reasons, on those sections of the complex that are economically important in pasture breeding. Inevitably these sections might well comprise robust-growing high polyploid apomicts. This has created the impression that the complex was an old one consisting of mostly obligate apomicts.

It was considered therefore that cytogenetic studies (especially embryo sac studies) of a naturally growing and unselected *E. curvula* Complex population might be well worth studying in an attempt to elucidate this problem.

MATERIAL

A region was selected in the Transvaal (South Africa), which included highveld, a transition area and lower bushveld. Seventeen collecting points were selected with three collections at each point in order to evaluate variation among as well as within collecting points over a reasonably varied area (Fig. 1).

Collecting points were selected at regular intervals on the lower bushveld and highveld, while those over the transition area were selected (with the help of Fig. 2) so that the bottom, slopes and summits of ridges would be included.

Herbarium specimens of each collection were made and identified at the National Herbarium in Pretoria, where they are now housed (Table 1).

It was decided that a minimum of fifty embryo sacs should be investigated for every plant. Additional embryo sacs of a specific plant were thus sectioned or new plants were collected when this number was not available from the collected material. More plants were therefore collected than were actually used in the study. All plants collected are reflected in Table 1 and given herbarium numbers. Those plants used in this study were, however, given additional numbers (Plant Numbers—Table 1) to identify those plants originating from one collecting point.

METHODS

The inflorescences for microtome studies were fixed in Navashin fixative (Stockholm modification—Maheshwari, 1939). Inbedding and staining techniques outline in Johansen (1940) were followed using Heidenheins Haematoxylin as nuclear stain and Orange G as counter stain.

The propionic carmine squash method of Pienaar (1955) was slightly modified for the study of microsporogenesis and chromosome numbers.

RESULTS

Although the study of embryo sac development was the main object of the present work, microsporogenesis and chromosome numbers were also investigated as far as possible. One big problem was, that by the time that microsporogenesis could be investigated (only after the embryo sacs were studied), the material had been left in the fixative too long.

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

† Department of Genetics, University of Pretoria.

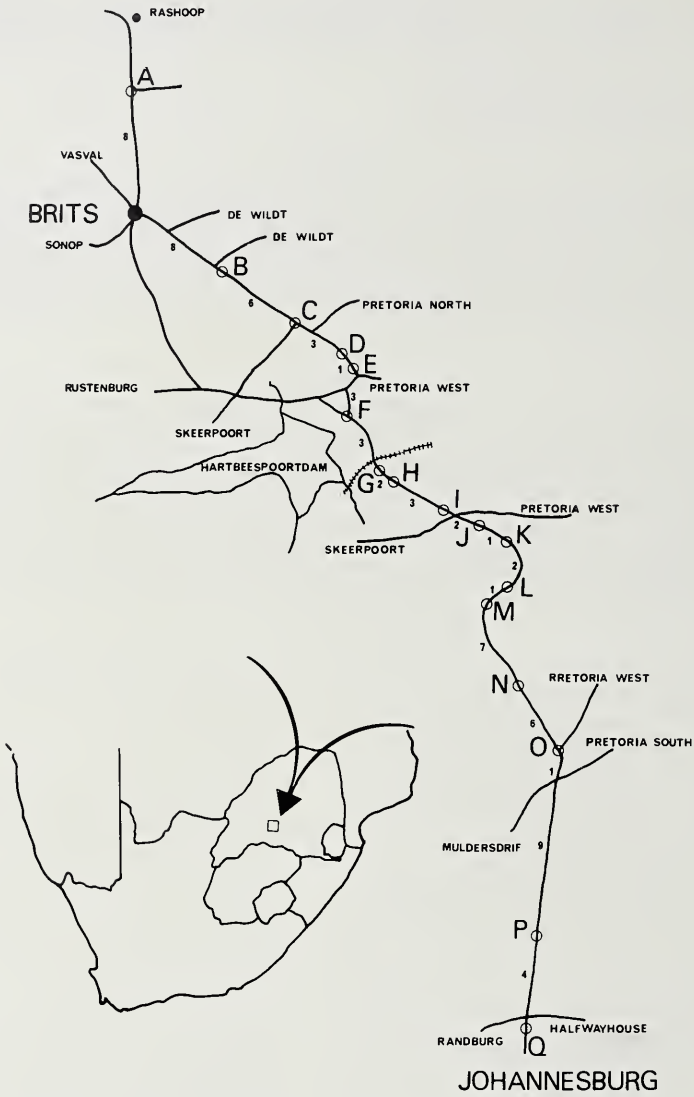


FIG. 1.—Map of the roads between Brits and Johannesburg indicating the collecting points A to Q as well as the distance in kilometres between them; collecting points A to E are defined as the lower bushveld, F to M as the transition area and N to Q as the highveld.

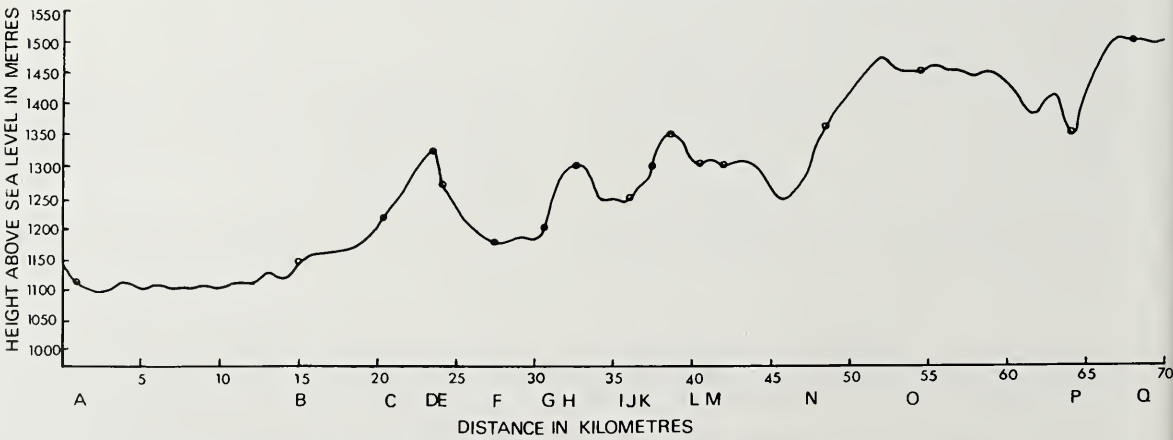


FIG. 2.—A graph indicating the collecting points with regard to the height above sea level and distance.

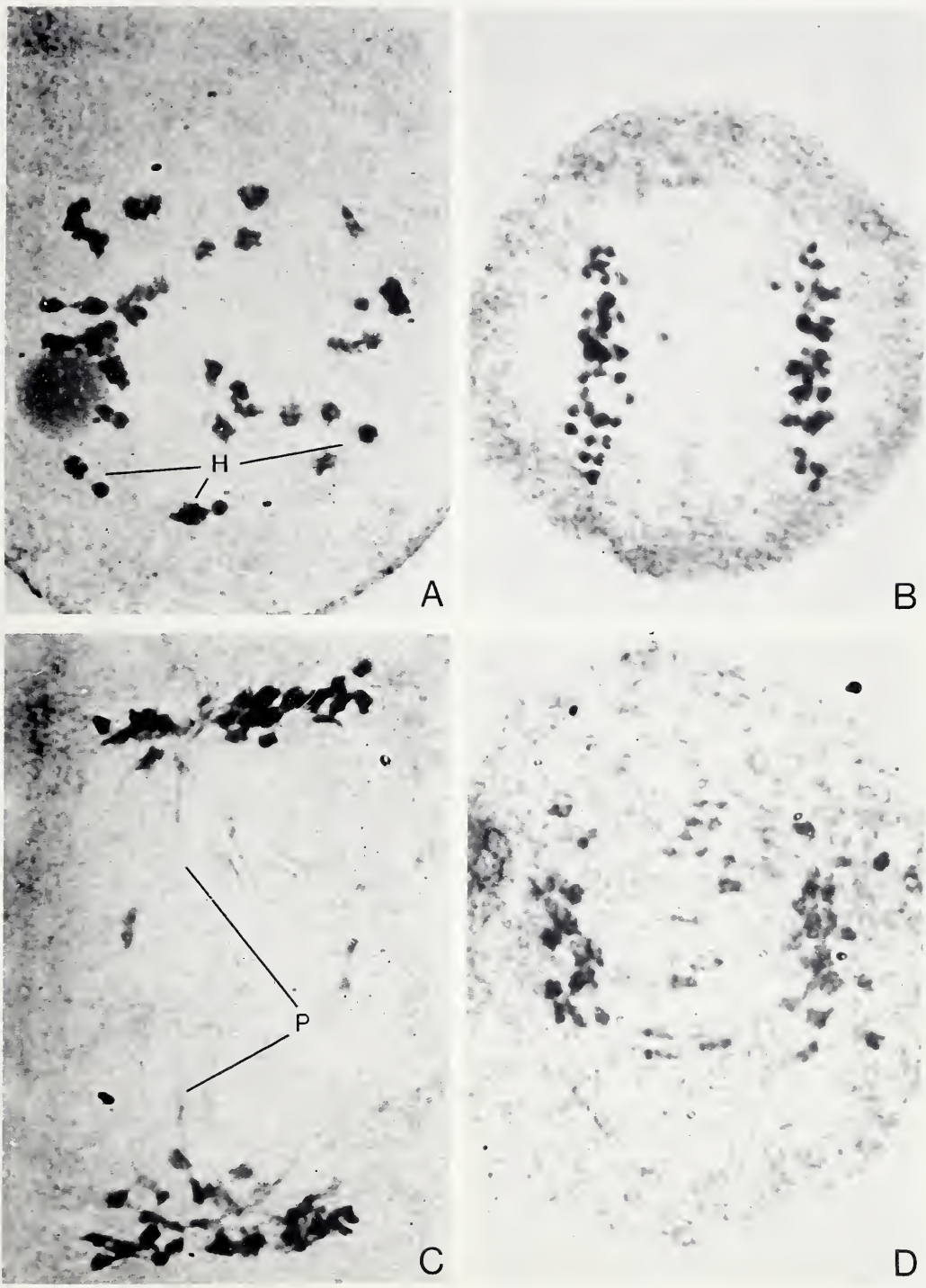


FIG. 3.—Microsporogenesis stages of some of the collections. A: Diakineses of a rather "regular" tetraploid with a few distinct heteromorphic bivalents (H) –collection L-3. B: Anaphase I of a rather "regular" hexaploid –collection H-2. C: Anaphase I of a rather "regular" hexaploid (two laggards with one undergoing chromatid segregation) as well as one paracentric inversion bridge (P) –collection J-1. D: Anaphase I of a very abnormal hexaploid (approximately 12 laggards, some of them undergoing chromatid segregation, can be seen) –collection G-3.

Because of the small and compact spikelets of *Eragrostis*, fixative penetration is poor with the result that the material deteriorates soon after fixation.

Analyses were made of the number of monovalents and laggards during metaphase I and anaphase I respectively and are recorded with the chromosome numbers in Table 2. The quality of the slides did not permit multivalent or any other more complex analyses.

Paracentric inversion bridges (Fig. 3C) were also encountered in collections C–2, C–3, H–3 and J–1. These bridges, however, occurred at a very low frequency (except for plant J–1 which had chromatid bridges in 16% of the anaphase I cells studied). Apart from indicating that the polyploids are probably segmental-allopolyploids, this information was considered too scanty to be of any further use. Another phenomenon that was conspicuous in a few collections, e.g. L–3, and that would support the segmental-allopolyploid nature of the plants was the occurrence of heteromorphic bivalents, where one chromosome was much larger than its partner (Fig. 3A).

The meiotic analysis showed that plants with low chromosome numbers tend to have "regular" meioses, whereas higher polyploids were inclined to have abnormal meioses although some variation occurred. A few groups could roughly be distinguished as regard chromosome number, microsporogenesis abnormalities and the locality from whence they came:

(1) Hexaploids with abnormal meisoses (all these plants are from the lower bushveld and the beginning of the transition area) (Fig. 3D).
(2) Hexaploids with rather "regular" meioses (these plants are from the transition area and the beginning of the highveld) (Fig. 3B).
(3) An octoploid with a relative "regular" meiosis (from the transition area).
(4) A pentaploid with, as expected, a very abnormal meiosis (from the transition area).
(5) Two tetraploids with relatively "regular" meioses (from the transition area).

A total of 3 902 embryo sacs was examined and the results are summarized in Table 1. It was found that 3 306 of these embryo sacs were apomictic by means of diplospory followed by parthenogenesis and pseudogamy while 99 were sexual monosporic Polygonum type (Maheshwari, 1950) embryo sacs. One hundred and nineteen embryo sacs were abnormal or divergent, while 378 were degenerated (Table 1).

DISCUSSION

Four factors were considered in attempting to evaluate the natural variation in the *E. curvula* Complex in the area of this study.

1. *Morphological variation in collected material*

It was quite striking that only true *E. curvula* was collected on the lower bushveld as well as the highveld, while true *E. curvula* as well as types which could not be judged as true were collected in the transition area (Table 1).

All the *E. chloromelas* types (true and not true types) were collected in the transition area. This indicates a great deal of variation, not only between, but also within collection points in the transition area.

2. *Variation in chromosome numbers*

The *E. curvula* Complex has a wide range of chromosome numbers, i.e. 2n=20, 40 and 60 (Pienaar, 1953) and 2n=50 (De Wet, 1954) for *E. curvula*, 2n=40 and 60–63 (Pienaar, 1953) for *E. chloromelas* and 2n=70 and 80 (Pienaar, 1953) for *E. robusta*. In this study an additional number of 2n=80 was found for *E. curvula* in the transition area (Table 1, plant H–3).

Although chromosome counts for only a few plants were made, it is clear that the numbers in the transition area are very variable (2n=40, 50, 60 and 80). The few plants in the lower bushveld and highveld, which were studied in this respect, all had 60 chromosomes and, although it is risky to draw any definite conclusions, it seems as if there might be a greater chromosome number variation in the transition area.

3. *Variation in microsporogenesis*

Table 2 shows clearly that the meioses of plants are inclined to become more regular as the transition area is approached from the lower bushveld. The two hexaploids on the highveld have rather "regular" meioses, but it would again be dangerous to draw any conclusions as to the significance of this phenomenon, because of the low number of plants investigated.

4. *Variation in embryo sac development*

Considerable difficulty was at first experienced with the classification of some of the sexual embryo sacs and, because it was important to calculate the exact degree of sexuality for every plant, this problem has been attended to in some detail (Vorster & Liebenberg, in press).

Sexual embryo sacs were sporadically found over the whole sampling area but they occurred at a higher frequency in the transition area (Table 1). Not only was there variation in the embryo sac development over the area as a whole, but also within collecting points.

This occurrence of a high percentage sexuality and obligate apomixis within one collecting point stresses the discontinuous variation that occurs in the embryo sac development of the complex.

CONCLUSIONS

The method used in this study to try and evaluate the natural variation in embryo sac development in a specific area, proved to be very satisfactory, especially because it showed that previous studies did not reflect a true picture of the occurrence of sexuality in this complex. It would seem that the group is far from being an old obligate agamic complex. Since several specimens in the transitional zone were *E. chloromelas* types and showed, together with one *E. curvula* type, fairly high sexuality, it may be that *E. chloromelas* is supplying the source of sexuality in this area.

Sexual embryo sacs occurred most frequently in the transition area. Microsporogenesis studies showed, furthermore, that the meioses were inclined to become more regular as the transition area was approached from the lower bushveld, while the transition area also contained plants with the most variable morphology as well as the most variable chromosome numbers.

From these results, one seems justified in expecting that one or more of the original sexual ancestors of this agamic complex may still be present in or near the transition area (east or west from it) as sampled by this study. According to Stebbins (1950) the variation pattern in the *Crepis* Complex indicated that in the vicinity of diploid sexual ancestors, variable facultative apomicts occurred, whereas obligate apomics with great morphological uniformity

TABLE 1. - Number and percentage embryo sac types found for the different specimens

Plant number	Collector's number (Vorster)	Herbarium identification	Chromosome number	Number diplosporic embryo sacs	Percentage diplosporic embryo sacs	Number sexual embryo sacs	Percentage sexual embryo sacs	Number abnormal embryo sacs	Percentage abnormal embryo sacs	Number degenerated embryo sacs	Percentage degenerated embryo sacs	Total embryo sacs investigated
A-1	2	E. curvula (Schrad.) Nees		43	50,59	2	2,35	10	11,76	30	35,29	85
	3	E. curvula (Schrad.) Nees										
A-2	4	E. curvula (Schrad.) Nees		46	83,64			4	7,27	5	9,09	55
A-3	5	E. curvula (Schrad.) Nees		40	71,43			8	14,29	8	14,29	56
B-1	6	E. curvula (Schrad.) Nees		51	60,71	2	2,38	3	3,57	28	33,33	84
B-2	7	E. curvula (Schrad.) Nees		59	89,39	2	3,03	3	4,55	2	3,03	66
B-3	8	E. curvula (Schrad.) Nees		30	85,71			2	5,71	3	8,57	35
	9	E. curvula (Schrad.) Nees										
	10	E. curvula (Schrad.) Nees										
	11	E. curvula (Schrad.) Nees										
C-1	12	E. curvula (Schrad.) Nees		43	67,19			7	10,94	14	21,88	64
	13	E. curvula (Schrad.) Nees										
C-2	72	E. curvula (Schrad.) Nees	60	72	96,00					3	4,00	75
C-3	73	E. curvula (Schrad.) Nees	60	57	91,94			1	1,61	4	6,45	62
D-1	14	E. curvula (Schrad.) Nees		62	88,57			3	4,29	5	7,14	70
	15	E. curvula (Schrad.) Nees										
	16	E. curvula (Schrad.) Nees										
	17	E. curvula (Schrad.) Nees										
	18	E. curvula (Schrad.) Nees										
D-2	74	E. curvula (Schrad.) Nees	60	80	94,12	1	1,18	1	1,18	3	3,53	85
D-3	75	E. curvula (Schrad.) Nees	60	111	84,73	3	2,29	4	3,05	13	9,92	131
E-1	19	E. curvula (Schrad.) Nees		47	95,92			1	2,04	1	2,04	49
	20	E. curvula (Schrad.) Nees										
	21	E. curvula (Schrad.) Nees										
	22	E. curvula (Schrad.) Nees										
E-2	76	E. curvula (Schrad.) Nees	60	81	89,01			1	1,10	9	9,89	91
E-3	77	E. curvula (Schrad.) Nees	60	60	88,24					8	11,76	68
F-1	23	E. curvula (Schrad.) Nees		56	91,80			1	1,64	4	6,56	61
F-2	24	E. curvula (Schrad.) Nees		47	94,00					3	6,00	50
	25	E. curvula (Schrad.) Nees										
	26	E. curvula (Schrad.) Nees										
	27	E. aff. curvula (Schrad.) Nees										
F-3	78	E. curvula (Schrad.) Nees	60	80	82,47	4	4,12	3	3,09	10	10,31	97
G-1	28	E. sp. aff. curvula (Schrad.) Nees		61	95,31	1	1,56			2	3,13	64
	29	E. curvula (Schrad.) Nees										
	30	E. curvula (Schrad.) Nees										
	31	E. curvula (Schrad.) Nees										
	32	E. curvula (Schrad.) Nees										
G-2	79	E. curvula (Schrad.) Nees	60	67	81,71	2	2,44	1	1,22	12	14,63	82
G-3	80	E. curvula (Schrad.) Nees	60	88	86,28	1	0,98	9	8,82	4	3,92	102
	33	E. curvula (Schrad.) Nees										
	34	E. curvula (Schrad.) Nees										
	35	E. aff. chloromelas Steud.										
	37	E. curvula (Schrad.) Nees										
H-1	81	E. curvula (Schrad.) Nees	60	64	84,21					12	15,79	76
H-2	82	E. curvula (Schrad.) Nees	60	62	81,58			4	5,26	10	13,16	76
H-3	100	E. curvula (Schrad.) Nees	80	105	87,50					15	12,50	120
I-1	38	E. curvula (Schrad.) Nees		46	75,41	2	3,28	3	4,92	10	16,39	61
	40	E. curvula (Schrad.) Nees										
	41	E. curvula (Schrad.) Nees										
I-2	83	E. curvula (Schrad.) Nees		62	84,93			2	2,74	9	12,33	73
I-3	84	E. curvula (Schrad.) Nees	50	67	83,75	1	1,25	2	2,50	10	12,50	80
J-1	85	E. curvula (Schrad.) Nees	60	87	91,58			4	4,21	4	4,21	95
J-2	86	E. curvula (Schrad.) Nees	60	84	84,00	2	2,00			14	14,00	100
	87	E. curvula (Schrad.) Nees										
J-3	101	E. curvula (Schrad.) Nees	60	116	87,88	8	6,06	1	0,76	7	5,30	132
K-1	42	E. curvula (Schrad.) Nees		58	93,55	2	3,23			2	3,23	62
	43	E. curvula (Schrad.) Nees										
K-2	44	E. chloromelas Steud.		47	67,14	7	10,00	2	2,86	14	20,00	70
K-3	45	E. curvula (Schrad.) Nees		48	82,76			4	6,90	6	10,34	58
	46	E. curvula (Schrad.) Nees										
	48	E. curvula (Schrad.) Nees										
	49	E. cf. chloromelas Steud.										
	50	E. curvula (Schrad.) Nees										
	51	E. curvula (Schrad.) Nees										
L-1	88	E. curvula (Schrad.) Nees	60	103	85,12	4	3,31	4	3,31	10	8,26	121
L-2	89	E. curvula (Schrad.) Nees		98	89,09	2	1,82	4	3,64	6	5,45	110
L-3	90	E. curvula (Schrad.) Nees	40	72	70,59	21	20,59	3	2,94	6	5,88	102
M-1	52	E. curvula (Schrad.) Nees		58	89,23					7	10,77	65
	54	E. cf. chloromelas Steud.										
M-2	55	E. chloromelas Steud.		45	65,22	12	17,39	3	4,35	9	13,04	69
	56	E. chloromelas Steud.										
	57	E. chloromelas Steud.										
M-3	91	E. chloromelas Steud.	40	86	74,14	13	11,21	4	3,45	13	11,21	116
N-1	92	E. curvula (Schrad.) Nees		51	85,00	1	1,67	3	5,00	5	8,33	60
N-2	93	E. curvula (Schrad.) Nees		50	94,34					3	5,66	53
N-3	94	E. curvula (Schrad.) Nees	60	48	94,12					3	5,88	51
O-1	58	E. curvula (Schrad.) Nees		66	95,65			2	2,90	1	1,45	69
	59	E. curvula (Schrad.) Nees										
	60	E. curvula (Schrad.) Nees										
	61	E. curvula (Schrad.) Nees										
O-2	95	E. curvula (Schrad.) Nees		45	83,33	1	1,85	3	5,56	5	9,26	54
O-3	96	E. curvula (Schrad.) Nees		69	89,61					8	10,39	77
P-1	62	E. curvula (Schrad.) Nees		68	93,15			4	5,48	1	1,37	73
	64	E. curvula (Schrad.) Nees										
	65	E. curvula (Schrad.) Nees										
P-2	66	E. curvula (Schrad.) Nees		56	83,58			2	2,99	9	13,43	67
P-3	97	E. curvula (Schrad.) Nees	60	111	93,28	4	3,36	3	2,52	1	0,84	119
Q-1	67	E. curvula (Schrad.) Nees		46	92,00	1	2,00			3	6,00	50
	69	E. curvula (Schrad.) Nees										
	70	E. curvula (Schrad.) Nees										
	71	E. curvula (Schrad.) Nees										
Q-2	98	E. curvula (Schrad.) Nees		52	94,55					3	5,45	55
Q-3	99	E. curvula (Schrad.) Nees		55	98,21					1	1,79	56

TABLE 2.- Analysis of the average number and frequency of laggards

Plant number	2n	Average number metaphase I monovalents	Average number anaphase I laggards	Cell frequency for the different monovalents/laggards numbers metaphase I / anaphase I											
				0	1	2	3	4	5	6	7	8	9	10	11
C-2	60	4,47	3,67	0	0 / 0,03	0,10 / 0,23	0,23 / 0,27	0,20 / 0,17	0,03 / 0,13	0,03 / 0,13	0,03 / 0,03	0,07 / 0	0,03 / 0	0	0
C-3	60	6,47	2,83	0 / 0,07	0 / 0,13	0 / 0,27	0,07 / 0,27	0,07 / 0,10	0,17 / 0,07	0,23 / 0,07	0,17 / 0,03	0,13 / 0	0,13 / 0	0,13 / 0	0
D-2	60	4,77	4,90	0	0	0,07 / 0	0,13 / 0,20	0,23 / 0,35	0,30 / 0,15	0,13 / 0,05	0,07 / 0,15	0,07 / 0,10	0	0	0
D-3	60	4,67	4,50	0	0	0,07 / 0,10	0,20 / 0,30	0,23 / 0,13	0,23 / 0,13	0,10 / 0,17	0,10 / 0,13	0,07 / 0,03	0	0	0
E-2	60	4,80	3,40	0	0	0,07 / 0,20	0,07 / 0,40	0,23 / 0,20	0,40 / 0,20	0,10 / 0	0,13 / 0	0	0	0	0
E-3	60	3,23	3,38	0	0,10 / 0	0,23 / 0,25	0,27 / 0,38	0,20 / 0,19	0,13 / 0,13	0,07 / 0,06	0	0	0	0	0
F-3	60	7,50	5,57	0	0	0	0,03 / 0,03	0,07 / 0,23	0,07 / 0,20	0,13 / 0,27	0,13 / 0,20	0,20 / 0,07	0,23 / 0	0,10 / 0	0,03 / 0
G-2	60	4,90	4,23	0	0	0,03 / 0,10	0,20 / 0,20	0,13 / 0,27	0,30 / 0,27	0,17 / 0,13	0,13 / 0,03	0,03 / 0	0	0	0
G-3	60	5,07	3,38	0	0	0,07 / 0,12	0,07 / 0,50	0,23 / 0,25	0,23 / 0,12	0,23 / 0	0,10 / 0	0,07 / 0	0	0	0
H-1	60	1,73		0,13 / -	0,27 / -	0,33 / -	0,27 / -	0	0	0	0	0	0	0	0
H-2	60	1,53	1,23	0,10 / 0,20	0,40 / 0,43	0,40 / 0,30	0,07 / 0,07	0,03 / 0	0	0	0	0	0	0	0
H-3	80	1,47	0,70	0,27 / 0,53	0,30 / 0,17	0,23 / 0,20	0,13 / 0,07	0,03 / 0,03	0,03 / 0	0	0	0	0	0	0
I-3	50	5,61	3,67	0	0	0 / 0,33	0,11 / 0	0,06 / 0,33	0,33 / 0,33	0,22 / 0	0,17 / 0	0,11 / 0	0	0	0
J-1	60	1,97	1,72	0,10 / 0,12	0,23 / 0,28	0,37 / 0,36	0,20 / 0,24	0,10 / 0	0	0	0	0	0	0	0
J-2	60	1,64	1,25	0,14 / 0,25	0,36 / 0,25	0,29 / 0,50	0,14 / 0	0,07 / 0	0	0	0	0	0	0	0
J-3	60	2,20	1,07	0,07 / 0,23	0,30 / 0,50	0,23 / 0,23	0,23 / 0,03	0,10 / 0	0,07 / 0	0	0	0	0	0	0
L-1	60	1,30	1,22	0,33 / 0,33	0,23 / 0,27	0,27 / 0,22	0,13 / 0,17	0,03 / 0	0	0	0	0	0	0	0
L-3	40	2,27[X]		0,09[X] / -	0,18[X] / -	0,32[X] / -	0,23[X] / -	0,14[X] / -	0,04[X] / -	0	0	0	0	0	0
M-3	40	0,60	0,40	0,53 / 0,68	0,33 / 0,24	0,13 / 0,08	0	0	0	0	0	0	0	0	0
N-3	60	2,10	1,44	0,07 / 0,24	0,33 / 0,32	0,27 / 0,24	0,17 / 0,16	0,10 / 0,04	0,07 / 0	0	0	0	0	0	0
P-3	60	0,80	0,88	0,37 / 0,38	0,43 / 0,38	0,20 / 0,25	0	0	0	0	0	0	0	0	0

[X] Diakinesis monovalents

were found far from them. The diploid *E. curvula* reported by Pienaar (1953) as well as the diploid sexual found by Voight (1971) in the variety *conferta* lends further evidence that at least some of the diploid sexual ancestors of the complex still exist.

In conclusion, it is clear from this study, however limited its scope, that the *E. curvula* Complex is inadequately known and understood. If any sense is to be made out of its problematic morphological variation pattern, it is clear that a complete cytogenetic study is called for. Such a study should include all related types and even species, over as much of their distribution area as possible. The present authors have already begun this task and it is hoped that in this way the relationships and therefore the taxonomy of the complex will be unravelled or at least better understood.

UITTREKSEL

Sitogenetiese studies is onderneem op die Eragrostis curvula *kompleks. Daar is drie plante by elk van die* 17 *versamelpunte geneem en bestudeer. Hierdie plante is geëvalueer ten opsigte van hul klassifikasie (morfologie) en kiemsakontwikkeling. Sommige van die plante se mikrosporogenese en chromosoomaantal kon ook bestudeer word. Die versamelpunte is uitgekies om 'n variabele omgewing, wat strek vanaf 'n laerliggende bosveld na die hoëveld, te verteenwoordig. Dit is gevind dat die kiemsakontwikkeling van die plante afkomstig vanaf die laerliggende bosveld sowel as die hoëveld vir alle praktiese doeleindes verpligte diplosporiese apomikte is, terwyl die plante afkomstig vanaf die oorgangsgebied verpligte sowel as fakultatiewe diplosporiese apomikte opgelewer het. Dieselfde patroon kon waargeneem word ten opsigte van die plantmorfologie, chromosoomaantal en mikrosporogenese.*

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A note on the flowers of *Halleria lucida*

C. H. STIRTON*

ABSTRACT

Studies of sunbirds (*Cinnyris* spp.) feeding on the nectar of flowers of *Halleria lucida* L. suggest that partial protandry may be operative in the breeding system of this cauliflorous tree. Attention is drawn to certain anomalies depicted in published botanical drawings. These anomalies are discussed in relation to the sequential development of the androecium and gynoecium in live flowers. *Colius colius*, the speckled coly, is reported to eat the fruits of *Halleria lucida*. This bird also feeds on nectar after piercing the base of the corolla tube.

RESUME

*NOTE SUR LES FLEURS D'*HALLERIA LUCIDA

Des observations sur la consommation de nectar par des souïmangas du genre Cinnyris *exploitant les fleurs d'*Halleria lucida *L. suggèrent qu'une protandrie partielle peut intervenir dans le système reproducteur de cet arbre cauliflore. On attire l'attention sur certaines anomalies figurant dans des dessins botaniques qui ont été publiés et on discute ces anomalies par rapport au développement séquentiel de l'androcée et du gynécée dans des fleurs vivantes.* Colius colius, *la veuve tachetée, est signalé comme mangeant les fruits d'*Halleria lucida. *Cet oiseau se nourrit également de nectar après avoir percé la base du tube de la corolle.*

Halleria lucida L. is one of the few cauliflorous trees in South Africa (Marloth, 1932). The massed red tubular flowers are visited regularly by various species of sunbirds (*Cinnyris*) and sugarbirds (*Anthobaphes*) and this has led to the belief that pollination is ornithophilous (Marloth, 1932. Vogel, 1954). This note has arisen from observations of *Cinnyris* spp. feeding on the flowers of a solitary tree of *H. lucida* growing in the National Botanical Gardens, Pretoria.

A close inspection of massed flower clusters revealed that each cluster was composed of flowers at different stages of development. Sequential dissections from bud stages to fully mature flowers suggested that partial protandry might operate as an outbreeding mechanism. It was found that the didynamous stamens expanded at different rates and that the stigma was always below the lowest pair of these stamens until their anthers had dehisced. This sequential development is shown in Fig. 1. Prior to the opening of the corolla lobes all four anthers were held at the same level, even though the filaments of the two pairs were adnate to the corolla tube at different levels. Steps 1–5 in Fig. 1 show the emergence of the anthers from the corolla mouth. The outer pair of anthers (deepest inserted) developed faster than the inner pair of anthers, so that by the time the inner pair had dehisced the outer pair had completely shed their pollen. The style expanded rapidly once dehiscence of the inner pair of anthers had begun and eventually either overtopped or attained the level of the outer pair of anthers. It was difficult to establish accurately the time of receptivity of the stigma, but it appears to have occurred once the stigma had reached the level of the inner pair of dehisced anthers.

Any interpretations of the phenomenon discussed above must be made cautiously for a number of reasons. Firstly, different authors have commented on different flower types in *Halleria lucida* and secondly, different patterns of development have been reported for the androecium and gynoecium. Sims (1815), who commented on a rudimentary fifth filament, compared this species to the genus *Lonicera* (Caprifoliaceae) in which Burman (Rar. Afric. 244, t. 89, fig. 2) had placed it. Verdoorn (1946) drew attention to anomalous flowers and commented as follows: "While the majority of flowers on this shrub are funnel-shaped with an oblique, somewhat 2-lipped mouth, several were found to be trumpet-shaped with the lobes equally spreading and 4 or 5 in number. In these examples the stamens were also equally disposed and not unilateral." Flowers observed in Pretoria approximated those in t. 961, fig. 4 (Flow. Pl. Afr., 1946) of Verdoorn's article. No abnormal flowers were found. Vogel (1954), however, has commented that the stamens and stigma hardly exsert from the corolla mouth and his Fig. 132: 4 closely approximates t. 961, fig. 8 described as an abnormal flower by Verdoorn. It is difficult to assess from these drawings, as well as from the t. 1744 (Bot. Mag. 41, 1815) described by Sims, whether the relative position of anthers and stigma can be ascribed to the artist having drawn flowers at different stages of development. If the flowers drawn were indeed mature, it must still be decided whether such flower types are abnormalities or whether they are normal and may possibly play an important rôle in the pollination strategy of the plant. This will require further field studies.

My assessment of partial protandry is derived from the observations outlined above. If this is correct, it would mean that a bird flying from flower to flower could conceivably transfer pollen from a flower with only one pair of anthers dehisced to a flower in which the stigma was completely exerted. This would constitute a measure of outbreeding if more than one plant was involved. On the other hand, the late emergence of the second pair of anthers, with their dehiscence occurring as it does with the elongation of the stigma, could guarantee inbreeding. Limited emasculation and bagging studies of flower clusters on the Pretoria plant indicated that autogamy was operative.

An important feature of this cauliflorous tree is that the flower clusters, consisting as they do of flowers at all levels of development, ensure a constant visitation over a long period by potential pollinators. As Vogel (1954) has indicated, the flowers are rich in nectar, but non-odoriferous. The fruits of this plant are relished by the speckled coly, *Colius colius*, which also pierces the base of the corolla tube to feed on the nectar.

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

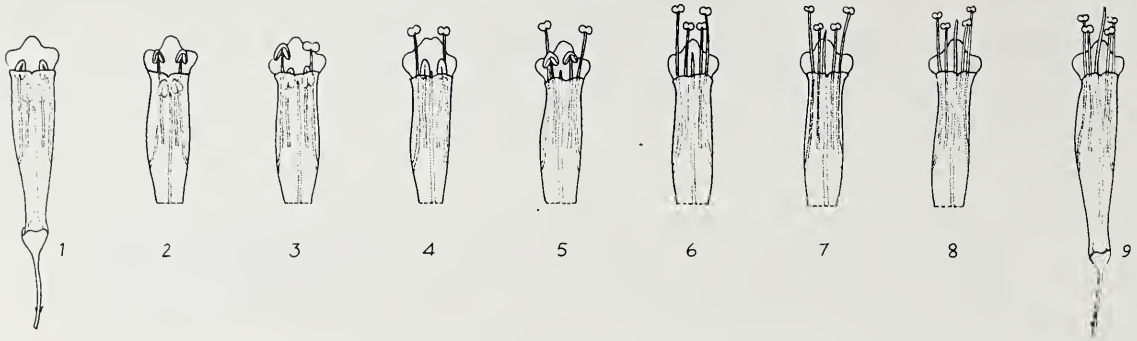


FIG. 1.—Sequential developmental stages of the flower of *Halleria lucida* once the corolla mouth has opened. 1, outer pair of stamens beginning to emerge from mouth, note stigma well below inner pair of stamens; 2, outer pair of stamens emerged from corolla mouth; 3, right hand anther of outer pair has begun dehiscence, while the inner pair has begun to emerge; 4, and 5, the outer pair has dehisced, the inner pair has emerged, as has the stigma; 6, inner pair has dehisced; 7-9, the stigma gradually elongates until it reaches the upper pair of anthers or overtops them.

An interesting feature of the dehisced anthers is that they are completely flattened, with the pollen-shedding surface facing downwards (i.e. towards the viewers of Fig. 1). This provides a maximum surface area to brush against any bird's bill or tongue inserted into the flower.

Detailed studies on a tree growing in the Kirstenbosch Botanical Gardens in Cape Town gave the same results as the studies carried out in Pretoria.

UITTREKSEL

Waarnemings op suikerbekkies (Cinnyris *spp.*) *wat op die nektar van blomme van* Halleria lucida *L. voed, skep die indruk dat gedeeltelike protrandrie werksaam mag wees in die voortplantingstelsel van hierdie boom, waar die blomme op die stam gedra word. Aandag word gevestig op sekere afwykings wat aangedui is in gepubliseerde plantkundige tekeninge. Hierdie afwykings word bespreek in verhouding tot die opeenvolgende ontwikkeling van die androecium en gynoecium in lewende blomme. Dit word berig dat* Colius colius, *die gespikkelde muisvoël, die vrugte van* Halleria lucida *eet. Hierdie voël voed ook op nektar nadat dit die basis van die kroonbuis deurboor het.*

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The pollination of *Canavalia virosa* by Xylocopid and Magachilid bees

C. H. STIRTON*

ABSTRACT

The floral morphology of *Canavalia virosa* (Roxb). Wight & Arn. is discussed in relation to pollination by *Xylocopa flavorufa* De Greer and *Megachile combusta* Sm. It was found that the relationship between size of flower and bee influenced the type of pollinating strategy and its success. Bees smaller than *M. combusta* proved ineffective pollinators.

RESUME

LA POLLINISATION DE CANAVALIA VIROSA *PAR LES ABEILLES XYLOCOPIDES ET MEGACHILIDES*

La morphologie florale de Canavalia virosa (*Roxb.*) *Wight & Arn. est discutée en rapport avec sa pollinisation par* Xylocopa flavorufa *De Greer et* Megachile combusta *Sm. On a constaté que la relation entre dimensions de l'abeille et de la fleur influence la technique de pollinisation et son succès. Des abeilles plus petites que* M.combusta *se sont avérées inefficaces pour la pollinisation.*

INTRODUCTION

Canavalia virosa (Roxb.) Wight & Arn. has been commonly known in South Africa as *Canavalia ferruginea* Piper. Although often confused with *C. ensiformis* (L.) DC. and *C. glochidiata* (Jacq.) DC., it is usually kept separate (Sauer, 1964, Verdcourt, 1971). However, it has been recently suggested that these three species may belong to one species. *C. ensiformis*, which includes wild and cultivated types (Westphal, 1974). The existence of this complex is not surprising if one considers the widespread cultivation of these plants in modern times as vegetables, fodder and cover crops. *C. virosa* is used here in the sense of Westphal (1974).

GEOGRAPHICAL DISTRIBUTION

C. virosa extends southwards from Arabia, Socotra and India through tropical Africa into north-east South Africa (Westphal 1974). Its distribution south of the Limpopo River is shown in Fig. 1.

FLORAL MORPHOLOGY

The general morphology of *C. virosa* has been adequately reviewed by Piper & Dunn (1922), Sauer (1964), Verdcourt (1971), and Westphal (1974). Piper *et al.* (1922) and Scott Elliot (1891) have written generalized accounts of the structural relationships of the various flower parts of *C. maritima* (Aubl.) Thours. and *C. ensiformis* (L.) DC. respectively. Vogel (1954) drew attention to analogies between the flowers of *C. maritima* and *Salvia africana* L. and also discussed pollination in both species. No account appears to have been given of the pollination of *C. virosa*. However, since, as Sauer (1964) has commented, *Canavalia* spp. generally have monotonous corollas and broad flowering schedules, it is to be expected that the genus is probably minimally adapted to specific pollinators. This implies that pollination is similar in most cases.

The flower structure of *C. virosa* hardly differs from the majority of known *Canavalia* spp. Flowers are generally held in an upright position with the standard facing downwards (e.g. Fig. 4 in Westphal, 1974). But, as Piper *et al.* (1922) pointed out, the flowers are commonly inverted i.e. standard below and facing upwards (e.g. Fig. 2 in Vogel, 1954). So far only inverted flowers have been observed in the Transvaal. A front view of such a flower is shown in Fig. 2: 1. An outstanding feature of this flower is the longitudinal bulging along the upper surfaces of the two wings (arrowed in Fig. 2: 1). This feature plays a prominent rôle in pollination and it is surprising that very little attention has previously been drawn to it. In Fig. 2: 2 and 3 the bulges are arrowed relative to their position to the standard (S) and keel (K). The two peglike callosities at the base of the standard (S) rest on the portion of wing tissue between the bulges and auricles of the wings. The auricles of the wings articulate with the standard at the point marked * in Fig. 2: 4. This articulation allows the keel and wings of both upright and inverted flowers to return to their original position after being depressed by a visiting insect.

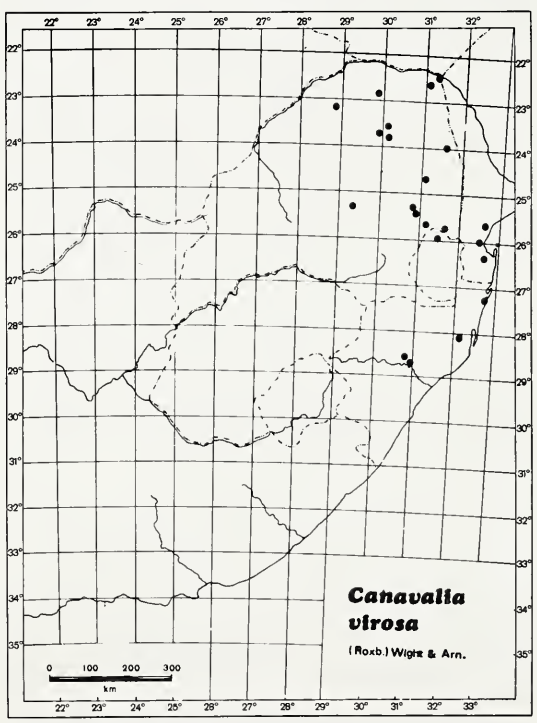


FIG. 1.—Known distribution of *Canavalia virosa* south of the Limpopo River (based on collections housed at the National Herbarium, Pretoria).

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.



FIG. 2.—*Canavalia virosa* showing various views of the flower: 1, front view of flower with an arrow indicating the opening caused by the bulging of the upper wing margins; 2, side view of flower with one wing and keel blade removed to show relative position of standard, wing and keel; 3, enlargement of centre portion of 2 showing wing pulled aside from the upper margin of the keel; 4, side view of opening flower to show relative position of wing and standard auricles. (K = keel, S = standard, W = wing). Arrows indicate longitudinal bulging of upper wing margins.

POLLINATING VECTORS AND THEIR STRATEGIES

In 1964 Sauer wrote that the available information on pollinating insects in *Canavalia* was meagre. Xylocopid bees have been reported to pollinate *C. maritima* e.g. *Xylocopa violacea* (Scott–Elliot, 1891) and *X. aestuans* (Piper *et al.* 1922). Vogel (1954) reported that *Anthophora* sp. also pollinates this species. Lepidoptera may also visit *C. maritima* (Scott–Elliot, 1891).

Recent field studies in the Nelspruit District of the eastern Transvaal, revealed that only two types of bees were able to depress the keel of *C. virosa* effectively. These bees differed markedly in size and adopted different pollinating strategies.

Xylocopa flavorufa De Greer (Fig. 3: 1) is a noisy fast-flying solitary bee found in coastal bush, montane savanna woodland, fynbos and dry savanna woodland (Watmough, 1974). Both male and female bees were caught feeding on the flowers of *C. virosa* in the Nelspruit Botanical Gardens. The bee lands on the inverted standard with some force causing the whole inflorescence to shudder. This insect fits snugly into the area presented by the standard and maintains a hold by grasping the standard mainly near the peg-like callosities. Its head lies near the opening formed by the longitudinal bulges of the wings of the flower (Fig. 4: 1). To trip the mechanism the bee raises its abdomen and thorax and then thrusts its head against the opening. This movement forces the keel and wings away from the staminal sheath thereby exposing the stigma and anthers, which dust the back of the bee's thorax. This sequence is identical to that shown in Fig. 2 of Vogel (1954) in which he depicts *Anthophora* sp. visiting flowers of *C. maritima*.

Megachile combusta Sm. (Fig. 3: 2) is a smaller and lighter bee than *Xylocopa flavorufa*. It is incapable of landing and maintaining its position as does *X. flavorufa*. This bee lands more or less on the side of the standard and after repeatedly slipping on the shiny area above the callosities, it eventually manoeuvres its body into a position that brings its abdomen into line with the tip of the keel (Fig. 4: 2). When it pushes its head against the opening (Fig. 2: 1) it depresses the keel and wings and causes its abdomen to brush against the exposed stigma and anthers. The wings and keel retract when the insect alights.

Apis mellifera L. and other bees smaller than *M. combusta* were common visitors to flowers of *C. virosa*. These bees were unable to depress the keel. They collected loose pollen and in flowers damaged by beetles that fed on nectar. Lepidoptera were common visitors.

DISCUSSION

In his discussion of the process of speciation in *Canavalia* Sauer (1964) noted that almost nothing was known about pollination or sterility barriers that could protect the divergent adaptations of subpopulations of diverging species. From his observations that isolated greenhouse plants could set seed, he deduced that facultative self-pollination

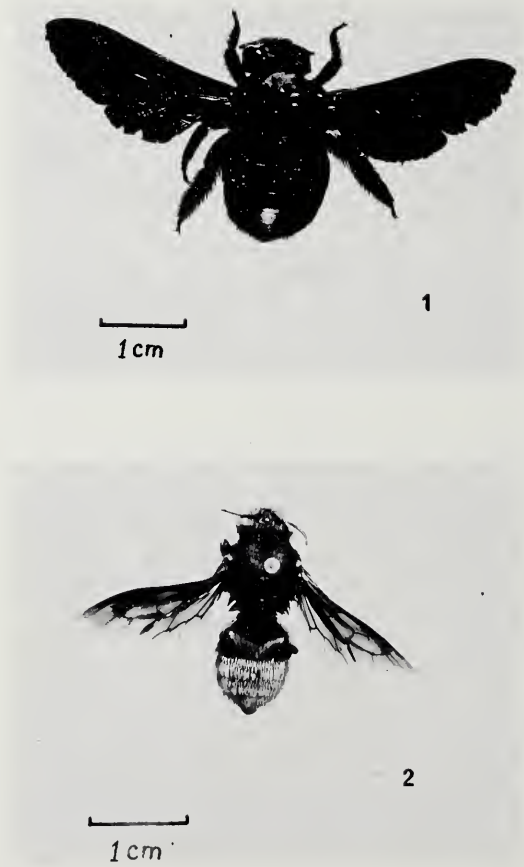


FIG. 3.—Photographs of bees. 1, *Xylocopa flavorufa*; 2, *Megachile combusta*.

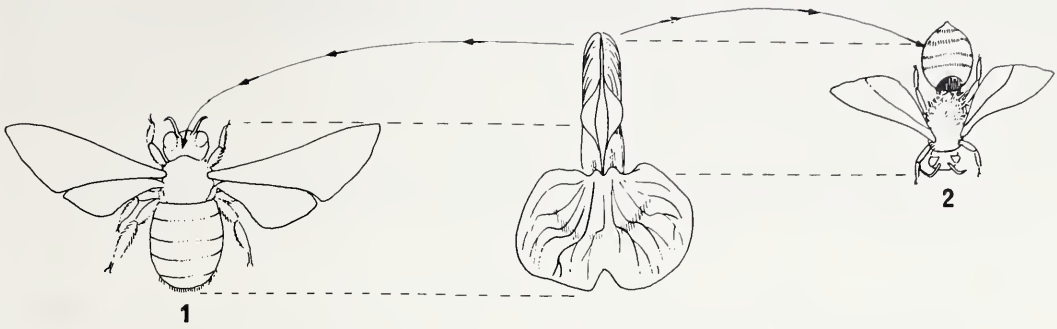


FIG. 4.—Positions adopted by *X. flavorufa* (1) and *M. combusta* (2) when operating the pollination mechanism of *Canavalia virosa*. Arrows indicate that pollen is dusted onto the thorax of *X. flavorufa* and onto the underside of the abdomen of *M. combusta*.

was possible, but he pointed out that the attractiveness of flowers to bumble bees and butterflies indicated cross-pollination.

Watmough (1974) noted that many indigenous Papilionaceae in Southern Africa apparently have no regular effective pollinators other than carpenter bees, which alone possess the power and weight necessary to operate the floral mechanisms. *Canavalia* appears, from the available evidence, to fall into such a class of plants. Plants of *C. virosa* in the eastern Transvaal tend to set between 2–4 seed pods per inflorescence, a factor which could indicate outbreeding as bees did not forage in inclement weather. If inbreeding was operative, one would expect a much higher seed set. It may, therefore, be advantageous to breed and release xylocopid bees in those areas where *C. virosa* and *C. ensiformis* are being cultivated. Watmough (1974) cites a number of references, which indicate that the introduction of these bees has improved the pollination and/or yield of a number of other agricultural crops.

Of the bees studied in this paper, *X. flavorufa* seems a more "natural" pollinator, whereas *M. combusta* and other bees smaller than it show every sign of being opportunists. *M. combusta* has "developed" a method whereby it can utilize nectar and pollen, but one which is not always successful.

Since few bees appear to be large enough to pollinate *C. virosa* successfully, it would appear that the large inverted flowers of this species constitute a possible isolating mechanism. *M. combusta* is the smallest known bee, which can operate the floral mechanism. A comparative study of sympatric *Canavalia* spp. with respect to pollinating vectors could give a better insight into the mechanisms which protect the divergent adaptations of subpopulations of diverging species, particularly those in complexes such as that of C. *ensiformis*.

ACKNOWLEDGEMENTS

My sincere thanks to Mrs E. Buitendag and Mr E. van Jaarsveld of the Lowveld Botanic Gardens, Nelspruit, for their help and hospitality; to Mr R. H. Watmough of the Plant Protection Research Institute, Pretoria, for naming the insect collection; to Miss M. Scott for the line drawings and to Mrs A. Romanowski for the photographs.

UITTREKSEL

Die blommorfologie van Canavalia virosa (*Roxb.*) *Wight & Arn. word bespreek in verhouding tot bestuiwing deur* Xylocopa flavorufa *De Greer en* Megachile combusta *Sm.. Dit is gevind dat die verhouding tussen grootte van blom en by die tipe bestuiwingstrategie en die sukses daarvan beïnvloed. Bye kleiner as* M. combusta *het ondoeltreffende bestuiwers blyk te wees.*

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Bothalia 12,2: 229-230 (1977)

Broad-spectrum pollination of *Plectranthus neochilus*

C. H. STIRTON*

ABSTRACT

The pollination ecology of *Plectranthus neochilus* Schltr. is discussed and compared with that of another garden plant, *Plectranthus barbatus* Andr.. Pollinators and flower visitors of *P. neochilus* include members of the Megachilidae, Anthophoridae, Syrphidae, Bombyliidae, Sphingidae, Apidae.

RESUME

EVENTAIL DE POLLINISATION DE PLECTRANTHUS NEOCHILUS

L'écologie de la pollinisation de Plectranthus neochilus *Schltr. est discutée et comparée avec celle d'une autre plante de lardin,* Plectranthus barbatus *Andr. On a relevé, parmi les insectes qui pollinisent et visitent les fleurs de* P. neochilus, *des représentants des Megachilidae, Anthophoridae, Syrphidae, Bombyliidae, Sphingidae, Apidae.*

INTRODUCTION

The insect-plant relationships of plants under cultivation are often very different from those of the same species growing under natural conditions. The "wild" pollinators may be absent in gardens and the successful transference of an outbreeding plant will then depend on either its potential for vegetative reproduction or on the plasticity of its pollination strategies.

This paper assesses the plant-insect relationships of *Plectranthus neochilus* Schltr., an indigenous species cultivated in gardens in the Pretoria area.

GENERAL MORPHOLOGY

P. neochilus is mostly a perennial, decumbent to erect, often much branched and bushy (Fig. 1), unpleasantly aromatic, 12-50 cm tall herb (Codd, 1975). Although it is variable in vegetative characters it is relatively constant in floral characters. The inflorescence is a 4-angled spikelike raceme 3-4 cm long when in the bud stage. It is composed of 4 rows of densely imbricate, ovate, acuminate bracts (Fig. 2A). Flowering proceeds by the gradual opening of each verticil of flowers. This is accompanied by the shedding of the bracts surrounding each verticil and by the elongation of the rhachis between the opened verticils (Fig. 2C). Thirteen spaced verticils can be seen in Fig. 2C, with the rhachis also clearly visible between the verticils. Open flowers can be seen in Fig. 2B.

POLLINATION ECOLOGY

Over a period of three weeks plants of *P. neochilis* were observed in the Pretoria National Botanic Gardens, Brummeria. They cover large areas in massed displays, a feature seldom found in the wild. These displays are rich sources of nectar and attract numerous insect visitors such as bees, hoverflies and butterflies. The following insects represent the commonest visitors:

Megachilidae.....	*Megachile maxillosa* Guér.
	Megachile chrysorrhoeae Gerst.
	Megachile sp. (leaf cutter)
	Megachile combusta Sm.
	Megachile sp. cf. combusta Sm.
Anthophoridae.....	*Xylocopa caffra* (L.)
	Xylocopa senior Vachal
	Xylocopa sichele Vachal
	Anthophora sp.
Apidae.....	*Apis mellifera L.*
Syrphidae.....	*Asarcina* cf. *rostrata* Wied.
Bombyliidae.....	unidentified flies
Sphingidae.....	*Macroglossum trochilus* (Hbn.)

Of these insects, only the bees effectively worked the pollination mechanism every time. The syrphids, bombylids and sphingids insert their probosci without touching either the androecium or gynoecium.

In all cases, the bees landed on the horizontal lower boat-shaped lip of the flower, depressing it and exposing the stamens and stigma (which then rubbed against the lower abdomen as the insect began



FIG. 1.—*Plectranthus neochilus* growing among rocks 8 km S.E. of Barberton. Note the large number of inflorescences. Photo: L. E. Codd.

* Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

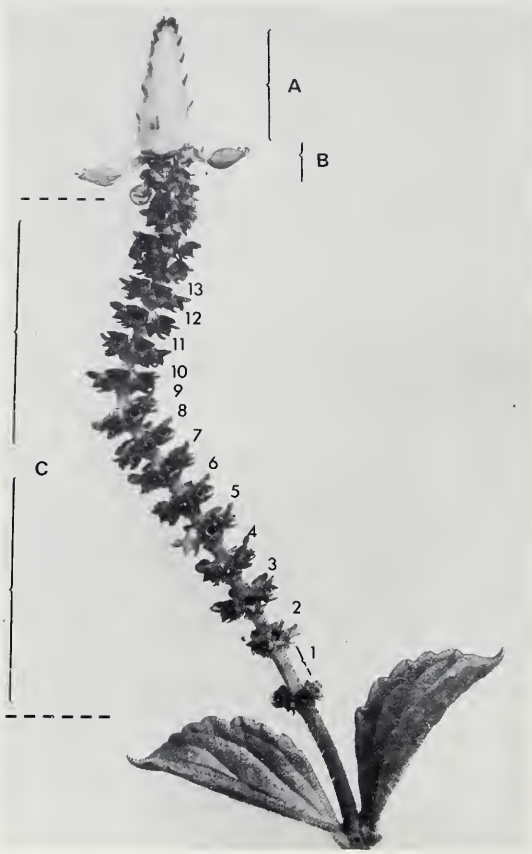


FIG. 2.—*Plectranthus neochilus*: A, region of densely imbricate, ovate, acuminate bracts; B, region of opening flowers; C, region of opened verticils showing gaps between the verticils (numbered 1–13). *Pole Evans* 4775, cultivated at Prinshof (1954–01–19).

feeding). The most active feeding times were between 11h00 and 14h00., especially on calm, bright and sunny days.

Scott Elliot (1891) recorded the following insects on *P. ecklonii* Benth.: *Apis mellifera* collecting pollen, a bombylid sucking and effecting cross-fertilization, as well as two lepidoptera.

Although the flower beds could not be observed continuously, it was clear that, as the inflorescences gradually opened and expanded, there were definite changes in the numbers and types of insects seen visiting the plants over a three week period. It is apparent that the gradual opening of the inflorescence verticil by verticil, the abundant nectar production, the small flowers, and many inflorescences on a single plant all ensure a steady visitation by pollinators over a long period.

During two months of observations in the wild, however, only megachilid bees have been observed visiting *P. neochilus.*

Plectranthus barbatus Andr. is an attractive garden plant cultivated in various parts of the world and, according to Codd (1975), it has become semi-naturalized in parts of South Africa. This plant is grown in the Pretoria National Botanic Gardens in the vicinity of *P. neochilus*, which is a less robust plant with smaller flowers. Of the insects visiting *P. neochilus*, only *Xylocopa sichele* Vachal, *X. senior* Vachal and *Macroglossum trochilus* (Hbn.) also visited *P. barbatus*, the latter two very rarely. Both species of *Plectranthus* are new feeding records for *M. trochilus* (Hbn.).

It may be concluded that *P. neochilus* possesses inherent features, which have enabled it to be visited by a broader spectrum of insect visitors in cultivation than in the wild. The limited "garden strategy" of *P. barbatus* needs further investigation, particularly with reference to its original habitat.

ACKNOWLEDGMENTS

My sincere thanks go to Dr R. H. Watmough for identifying the insects and to Dr L. E. Codd for his interest and identification of the *Plectranthus* material.

UITTREKSEL

Die bestuiwings-ekologie van Plectranthus neochilus *Schltr. word bespreek en vergelyk met die van 'n ander tuinplant*, P. barbatus *Andr.. Bestuiwers en blombesoekers van* P. neochilus *sluit lede van die Megachilidae, Anthophoridae, Syrphidae, Bombyliidae, Sphingidae en Apidae in.*

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Bothalia 12, 2: 231–237 (1977)

Freshwater algae of Southern Africa. II. *Triplastrum spinulosum* from the Transvaal

M. ISABELLA CLAASSEN*

ABSTRACT

The presence of *Triplastrum spinulosum* (Kisselev) Gauthier-Lièvre (Desmidiaceae) in South Africa is reported for the first time. The characters of *T. spinulosum* varieties *spinulosum*, *indicum* (Iyengar & Ramanathan) Gauthier-Lièvre and *africanum* Gauthier-Lièvre were found to be exhibited by specimens collected at Ottosdal in the south-western Transvaal. The differences among specimens of the populations studied are ascribed to variation within one variable species and therefore the varieties *indicum* and *africanum* are relegated to synonymy.

RESUME

ALGUES DULCICOLES D'AFRIQUE AUSTRALE. II. TRIPLASTRUM SPINULOSUM *DU TRANSVAAL*

La présence de Triplastrum spinulosum (*Kisselev*) *Gauthier-Lièvre* (*Desmidiaceae*) *en Afrique du Sud est signalée pour la première fois. On a constaté que les caractéristiques des variétés* spinulosum, indicum (*Iyengar & Ramanathan*) *Gauthier-Lièvre et* africanum *Gauthier-Lièvre de l'espèce* T. spinulosum *se rencontrent dans les spécimens récoltés à Ottosdal dans le sud-ouest du Transvaal. Les différences entre spécimens des populations étudiées sont attribuées à la variation intraspécifique d'une espèce variable et les variétés* indicum *et* africanum *sont dès lors placées en synonymie.*

INTRODUCTION

Samples containing *Triplastrum spinulosum* were collected by the author during April 1972 and February 1975 from a small pan 16 km east of Ottosdal in the south-western Transvaal and by Mr G. Germishuizen, Botanical Research Institute, Pretoria, during February 1974 from a small pool on the banks of the Nyl River on the farm Mosdene near Naboomspruit, central Transvaal.

Both habitats contain water during the rainy season, but may dry up partially or completely during the dry season (winter). During December 1974, which was an exceptionally dry summer, the Ottosdal pan was completely dry.

The hydrogen-ion concentration and the temperature of the water at the time of collection were pH 7,7 and 24°C, and pH 7,5 and 27°C for April 1972 and February 1975 respectively at Ottosdal and pH 6,1 and 26°C at Mosdene.

METHODS

The material was preserved with 4% formalin. Slides were made by mounting a sample droplet in a drop of glycerine. The methods used for the drawings and photomicrographs were the same as those given in the first paper of this series (Claassen, 1973).

OBSERVATIONS AND DISCUSSION

Iyengar and Ramanathan (1942) found a desmid in material collected during December 1940 in a paddy field near Madras, South India, which resembled the species *Triploceras abbreviatum* Turner (Krieger, 1937; Turner, 1892) and *Triploceras simplex* Allorge (Krieger, 1937). One of the main characters of the genus *Triploceras* Bailey is the presence of numerous whorls of knotlike projections (verrucae). As this character was lacking in both Turner's and Allorge's species as well as in their own taxon, Iyengar and Ramanathan (1942) decided to establish the new genus *Triplastrum* to accommodate these taxa, the constituent species being *Triplastrum indicum* Iyengar & Ramanathan, the desmid collected near Madras, *Triplastrum abbreviatum* (Turner) Iyengar & Ramanathan and *Triplastrum simplex* (Allorge) Iyengar & Ramanathan. However, they were unaware of the existence of *Triploceras spinulosum* Kisselev (Krieger, 1937), the description of which was based on a single specimen collected in Turkestan in 1930. *Triploceras spinulosum* closely resembles *Triplastrum indicum* and in 1960 Gauthier-Lièvre reduced the latter to a variety of the former, thus *Triplastrum spinulosum* (Kisselev) Gauthier-Lièvre var. *indicum* (Iyengar & Ramanathan) Gauthier-Lièvre.

Gauthier-Lièvre (1960) also described a new variety based on material collected in Africa, namely *Triplastrum spinulosum* var. *africanum*. The name of this new variety proposed by Gauthier-Lièvre was not validly published, however, since it was not accompanied by a Latin description or diagnosis as stipulated by Article 36 of the International Code of Botanical Nomenclature (Stafleu, 1972).

Turner (1892) described the apices of *Triploceras abbreviatum* as three- or four-lobed. Iyengar and Ramanathan (1942) incorporated this into their description of the genus *Triplastrum*. Krieger (1937) mentioned only three-lobed apices in his description of *Triploceras abbreviatum* Turner, and Gauthier-Lièvre mentioned only three-lobed apices in her description of the genus *Triplastrum*. In the material collected in the Transvaal the Ottosdal specimens have either three-lobed apices (Figs 1–3, 16 – upper cell, 17–22, 31, 32, 33 – cell on left, 34–38) or four-lobed apices (Figs 4, 9, 16 – lower cell, 25, 33 – cell on right) while some specimens have one semicell with a three-lobed apex and the other semicell with a four-lobed apex (Figs 10, 11, 26–28, 39). The Mosdene specimens have only four-lobed apices (Figs 5–8, 14).

Gauthier-Lièvre (1960) described *Triplastrum spinulosum* var. *spinulosum* as having weakly dilated apices, divided into three hardly divergent lobes which are bi-, tri- or quadridenticulate. Krieger's figure of this variety (1937, Pl. 53, Fig. 7), one of Gauthier-Lièvre's figures of her var. *africanum* (1960, Fig. 2t, cell on left), and Figs 1 and 13 (upper semicell) in the present paper as well as some of the specimens with four-lobed apices (Figs 7, 8, 14) resemble one another in that the apices are weakly dilated, and the polar lobes hardly divergent and bi- or tridenticulate and seldom quadridenticulate (Fig. 13).

According to Gauthier-Lièvre (1960), *Triplastrum spinulosum* var. *indicum* differs from the typical variety in its larger dimensions and longer more divergent polar lobes. Iyengar and Ramanathan's figures for

* Department of Botany, University of Pretoria, Pretoria.

this variety agree with Figs 2 (lower semicell) and 17 (cell on left) of the present paper as well as with some of the cells with four-lobed apices (Figs 4–6). The dimensions of these cells overlap both those of the type and var. *indicum*.

Triplastrum spinulosum var. *africanum* (Gauthier-Lièvre, 1960) differs from the typical variety in that the cells are slightly narrower below the apices and the polar lobes are strongly divergent, bidenticulate and seldom tridenticulate. The majority of the Ottosdal specimens (Figs 2 – upper semicell, 3, 19–22, 31, 32, 34–38) agree with Gauthier-Lièvre's figures for this taxon (1960, Figs 2q–t), but bidenticulate and tridenticulate polar lobes are approximately equal.

Iyengar and Ramanathan (1942) observed two chloroplasts each with a central pyrenoid in each semicell. Gauthier-Lièvre (1960) reported 1 or 2 pyrenoids per semicell for the type and 1–3 pyrenoids for her var. *africanum*. In the material collected in Transvaal, the majority of the specimens observed had two chloroplasts per semicell (Figs 1, 2, 4–8, 11, 12, 14, 19, 21, 23, 24, 26–28, 31, 32, 41), some had three chloroplasts per semicell (Figs 9, 25) or one semicell contained two chloroplasts and the other three (Figs 3, 20, 22). Each of these chloroplasts contained a central pyrenoid. Only a few specimens were observed in which the delineation of the chloroplasts was indistinct and there appeared to be only one chloroplast per semicell, but each contained two pyrenoids.

In the Ottosdal material one specimen (Figs 9, 25) was found which was considerably larger than the others: length without spines 141 μm, with spines 144 μm; maximum width 14 μm; width of isthmus 11 μm; width of apices 17–18, 5 μm. If this specimen is also taken into consideration, the dimensions of the Transvaal specimens overlap those of Gauthier-Lièvre's three varieties of *Triplastrum spinulosum*. The dimensions of the other Transvaal specimens are as follows:

	Ottosdal	*Mosdene*
length without spines	61–97 μm	56–66 μm
length with spines...	63–102,5 μm	59–68 μm
maximum width.....	9–11 μm	9,3–10 μm
width of isthmus....	8,5–10,5 μm	8,8–9,3 μm
width of apex.....	11–18 μm	10, 5–14 μm

Zygospores, found in the Ottosdal material collected during April 1972 (Figs 17, 18, 34–39), resemble those found by Iyengar and Ramanathan (1942) but are slightly smaller. The dimensions are 34–38 $\times$ 36–40 μm.

When all the characters found in the Transvaal specimens were taken into consideration it was decided that the specimens studied belonged to one species, namely *Triplastrum spinulosum* and that the two varieties *indicum* and *africanum* should be regarded as synonyms.

The two varieties are thus placed into synonymy and the circumscription of the species is amplified.

Triplastrum spinulosum (*Kisselev*) *Gauthier-Lièvre* in Revue Algol., 5, 1960, p. 64.

Syn.: *Triploceras spinulosum* Kisselev in Trans. Uzbekistan Inst. Tropic. Med. 1, 1930, p. 50, Pl. 4, Fig. 5; Krieger in Rabenhorst's Kryptogamenflora 13(1), 1937, p. 449, Pl. 53, Fig. 7.

Triplastrum indicum Iyengar & Ramanathan in J. Indian Bot. Soc., 21, 1942, p. 228, Figs 1–5. *T. spinulosum* (Kisselev) Gauthier-Lièvre var. *indicum* (Iyengar & Ramanathan) Gauthier-Lièvre in Revue Algol., 5, 1960, p.64. – var. *africanum* Gauthier-Lièvre, l.c. Pl. 64, Fig. 2, q-t, non rite publ.

Diagnosis

Cellulae parvae, circiter 6–10–plo longiores quam latiores, in medio leviter at manifeste constrictae; semicellulae rectae, cylindricae, lateribus paene parallelis vel leviter a basi paene usque ad apicem attenuatis, apices aliquatenus inflati, trilobi vel quadrilobi; qui lobi singuli 2–4 spinas breves ferunt; cellulae paries incolor, pori perparvuli. Chloroplasti axiales bini vel terni in semicellulis singulis, in seriem mediam dispositi, quorum unicuique laminae radiantes vel stellatae cum pyrenoide medio. Zygospora sphaerica (-subsphaerica) pariete spisso, margine crenato. Longitudo sine spinis 56–99, 5 (141) μm, cum spinis 59–105 (144) μm; latitudo ad basim semicellulae 9–14 μm; isthmi latitudo 8, 5–12 μm; apicis latitudo 11–18 (18,5) μm; zygospora 36–42 $\times$ 38–42 μm.

Cells small, about 6–10 times longer than broad, with a slight but well-defined median constriction; semicells straight, cylindrical, with sides nearly parallel or slightly attenuated from base to just below the apex; apices more or less inflated, three- or four-lobed, lobes slightly to strongly divergent, each lobe bearing 2–4 short spines; cell wall colourlesss, pores minute. Chloroplasts axial, 1 (?) or 2–3 in each semicell, arranged in a median series, each chloroplast with radiating plates (stellate) and a central pyrenoid. Zygospore spherical to subspherical, thick-walled, margin crenate. Length without spines 56–99,5 (141) μm, with spines 59–105 (144) μm; maximum width near base of semicell 9–14 μm; width of isthmus 8,5–12 μm; width of apices 11–18 (18,5) μm; zygospore 38–42 $\times$ 36–42 μm.

The geographical distribution of this species is:

Asia.—Turkestan (in a rice-swamp near Weliko-Alexewskoje). India (in a paddy field near Madras, December)

Africa.—Sudan (in a swamp of the River Niger near Gao, December). French Equatorial Africa (Ubangi-Shari, February). Uganda (in a swamp on the road from Masaka to Kampala, August). Transvaal (in a small pool on the banks of the Nyl River near Naboomspruit, February; in a small pan near Ottosdal, February and April).

It seems that this species is very rare and that usually only a few specimens are found in samples collected. In the samples collected near Ottosdal during April 1972, however, it was fairly abundant.

As could be expected in a fairly large population anomalous specimens were also found. In the Ottosdal material one specimen was found where, in each semicell, one of the polar lobes was under-developed, without spines and somewhat subapical (Figs 12, 41). In another specimen only one of the semicells was like this (Fig. 13, lower semicell). Several asymmetrical cells were found (Figs 11, 29, 40) and one very narrow semicell was observed (Fig. 30). The most anomalous specimen was a single semicell with a prominent basal inflation encircled by a whorl of eight lobes similar to the polar lobes (Figs 15, 42–44). In the Mosdene material one anomalous specimen was found with the polar lobes of one semicell undeveloped (Fig. 14).

ACKNOWLEDGEMENTS

I wish to thank the Council for Scientific and Industrial Research and the Research Committee of the University of Pretoria for financial assistance, Mr G. Germishuizen for collecting the Mosdene samples and Prof. Dr H. L. Gonin, who kindly prepared the Latin diagnosis.

UITTREKSEL

Triplastrum spinulosum (*Kisselev*) *Gauthier-Lièvre* (*Desmidiaceae*) *is vir die eerste keer in Suid-Afrika aangetref. Daar is gevind dat verteenwoordigers*

wat naby Ottosdal in die suid-westelike Transvaal versamel is die kenmerke van T. spinulosum *variëteite* spinulosum, indicum (*Iyengar & Ramanathan*) *Gauthier-Lièvre en* africanum *Gauthier-Lièvre weerspieël. Verskille tussen verteenwoordigers van hierdie populasie word as variasie in dieselfde takson aanvaar en die variëteite* indicum *en* africanum *word dus as sinonieme beskou.*

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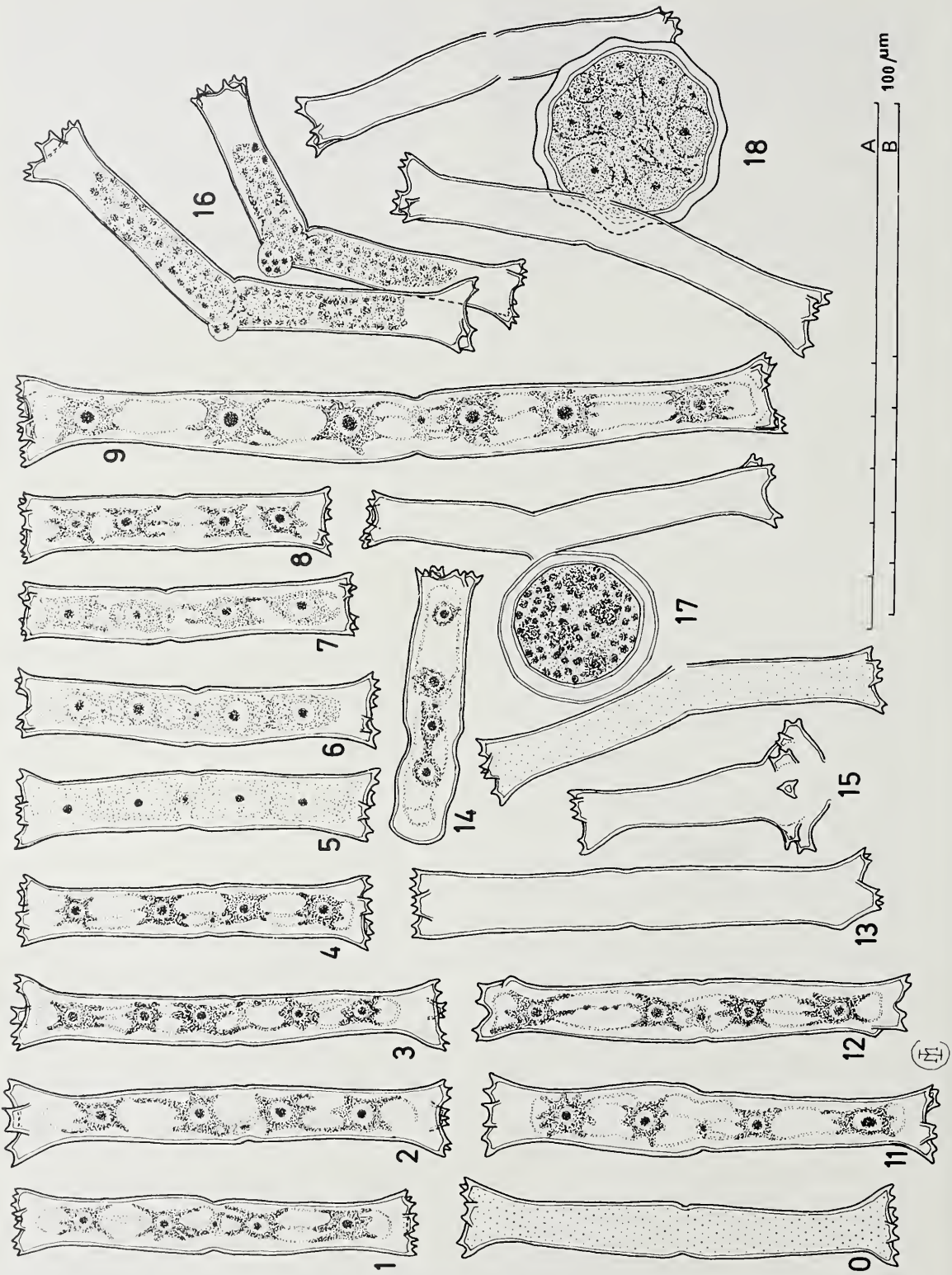
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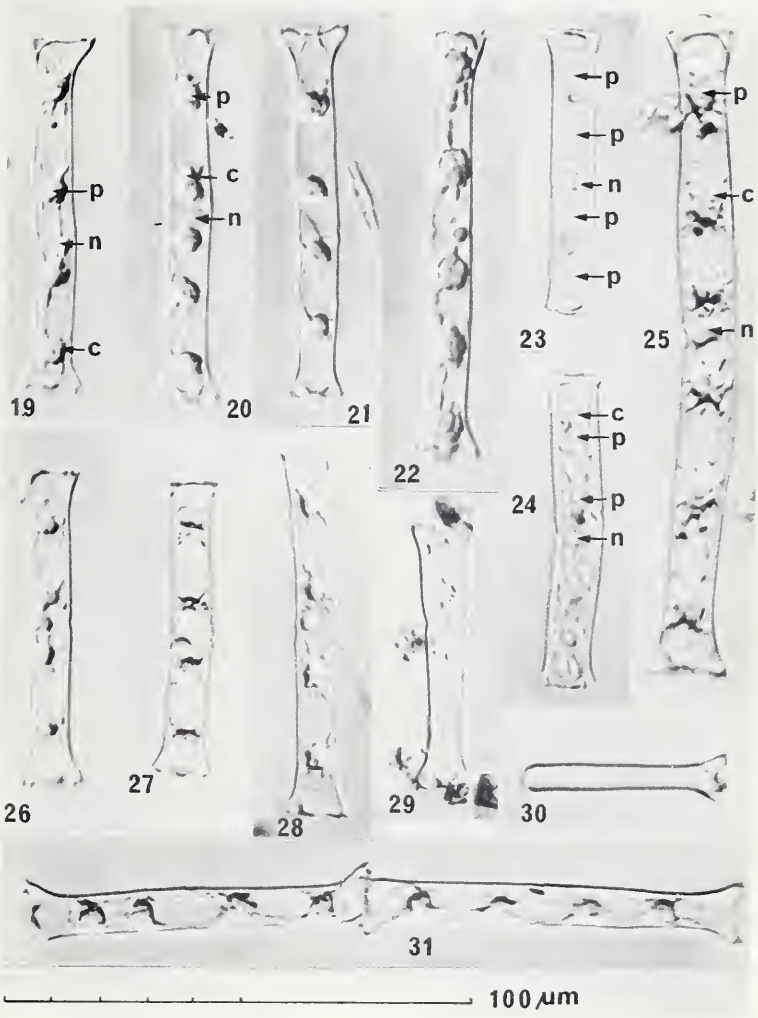
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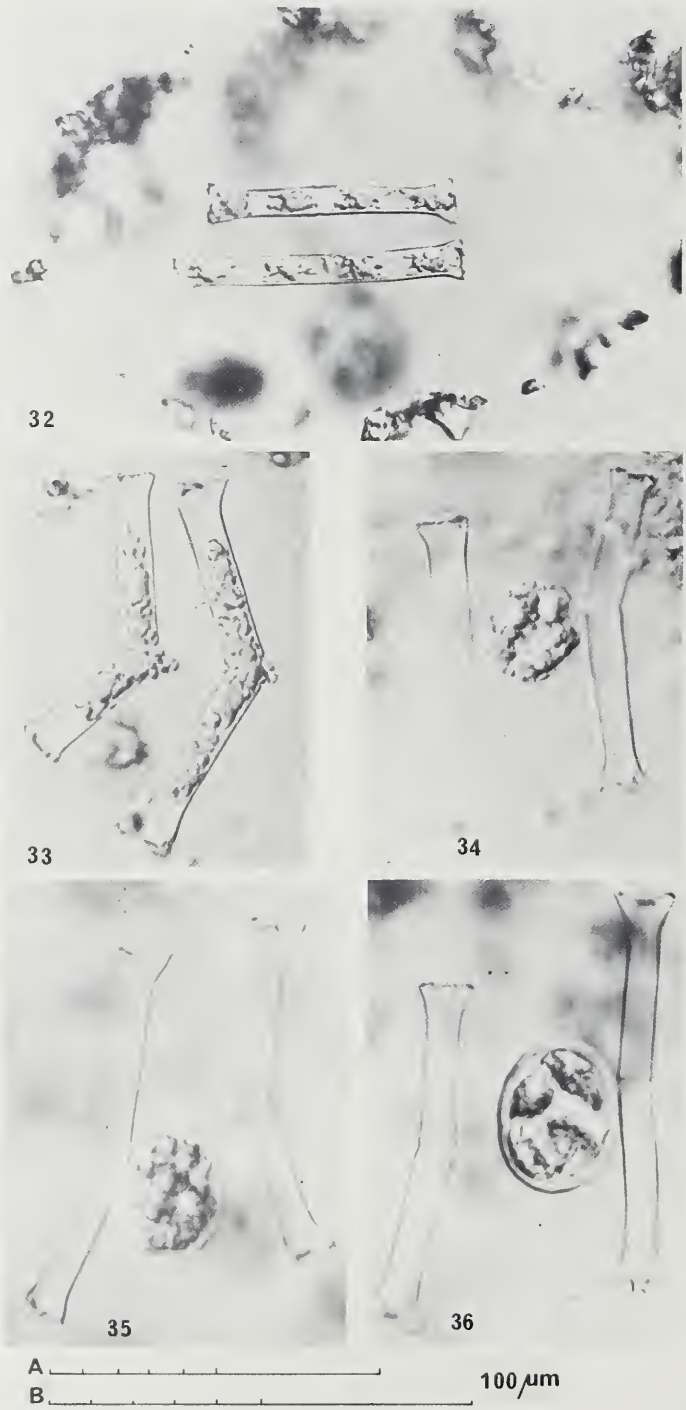
* The original spelling of the name of this genus by its authors was *Ichthyocercus* (West, W. & G. S. West, 1897, Welwitsch's African freshwater Algae, *J. Bot.*, 35: 80).



FIGS 1–18.—Drawings of *Triplastrum spinulosum*. 1, cell with three-lobed apices, lobes tridenticulate; 2, cell with three-lobed apices, lobes bi- or tridenticulate; 3, cell with one semicell containing three chloroplasts and the other semicell two; 4–8, cells with four-lobed apices, lobes bi- or tridenticulate; 9, large specimen with four-lobed apices, lobes tridenticulate, each semicell with three chloroplasts; 10, cell with one three-lobed and one four-lobed apex, lobes bi- or tridenticulate; 11, asymmetrical cell with one three-lobed and one four-lobed apex, lobes bidenticulate; 12, anomalous cell with one polar lobe in each semicell under-developed, without spines and slightly subapical, normal lobes bidenticulate; 13, anomalous cell with one polar lobe in one semicell under-developed, without spines and slightly subapical, normal lobes bi-, tri- or quadridenticulate; 14, anomalous cell with polar lobes of one semicell undeveloped; 15, anomalous semicell with a prominent basal inflation encircled by a whorl of eight lobes; 16, conjugating cells showing protuberances; 17, conjugating cells with young zygospore; 18, conjugating cells with mature zygospore. (Figs 1–4, 9–12 and 15–17: scale B. Figs 5–8, 13, 14 and 18: scale A).



FIGS 19–31.—Photomicrographs of *Triplastrum spinulosum*. 19, 21, cells with three-lobed apices and two chloroplasts per semicell; 20, 22, cells with three-lobed apices, one semicell with two chloroplasts and the other semicell with three; 23, 24, cells with four-lobed apices; 25, large specimen with four-lobed apices and each semicell with three chloroplasts; 26–28, cells each with the upper apex four-lobed and the lower apex three-lobed; 29, asymmetrical cell with upper semicell broader than lower semicell; 30, abnormally narrow semicell; 31, two cells after division remaining attached to each other. (c, chloroplast; p, pyrenoid; n, nucleus).



FIGS 32–36.—Photomicrographs of *Triplastrum spinulosum* 32, two cells just before conjugation, the dirt particles represent the margin of the mucilaginous envelope; 33, conjugating cells showing protuberances; 34, conjugating cells with young zygospore; 35, 36, further stages in developement of zygospore. (Fig. 32: scale A. Figs. 33–36: scale B).



FIGS 37–44.—Photomicrographs of *Triplastrum spinulosum*. 37, immature zygospore showing crenate margin; 38, 39, mature zygospores; 40, asymmetrical cell; 41, anomalous cell with one polar lobe in each semicell under-developed, without spines and slightly subapical; 42–44, anomalous semicell with a prominent basal inflation encircled by a whorl of eight lobes, photographed at various focussing adjustments.

Bothalia 12, 2: 239–245 (1977)

Freshwater algae of Southern Africa. IV. Some Micrasteriae from Rhodesia, including a new species

M. ISABELLA CLAASSEN*

ABSTRACT

Micrasterias ambadiensis (Grönblad & Scott) Thomasson, *M. crux-melitensis* (Ehrenberg) Hassall forma *minor* Turner, *M. decemdentata* (Nägeli) Archer, *M. pinnatifida* (Kützing) Ralfs var. *incudiformis* West & West, *M. radiata* Hassall var. *brasiliensis* Grönblad sensu lato, and *M. tropica* Nordstedt var. *tropica* are discussed. A new species, *M.* **schweickerdtii** Claassen, is described.

RESUME

ALGUES DULCICOLES D'AFRIQUE AUSTRALE. IV. QUELQUES MICRASTERIAE DE RHODESIE, INCLUANT UNE NOUVELLE ESPECE

On discute Micrasterias ambadiensis *(Grönblad & Scott) Thomasson,* M. crux-melitensis *(Ehrenberg) Hassall forma* minor *Turner,* M. decemdentata *(Nägeli) Archer,* M. pinnatifida *(Kützing) Ralfs var.* incudiformis *West & West,* M. radiata *Hassall var.* brasiliensis *Grönblad sensu lato, et* M. tropica *Nordstedt var.* tropica. *Une nouvelle espèce est décrite*: M. **schweickerdtii** *Claassen.*

INTRODUCTION

A sample containing a rich assemblage of desmids was given to me by Prof. Dr H. G. W. J. Schweickerdt, formerly head of the Department of General Botany, University of Pretoria. He collected the material during July 1957 from a small pool on dolomite rocks near Rusape, Rhodesia, but provided no physical or chemical data.

The sample contained seven different *Micrasterias* taxa amongst a number of other desmids. Although this sample was poorer in taxa, the taxon-composition showed a remarkable resemblance to that of Lake Ambadi, Sudan (Grönblad, Prowse & Scott, 1958).

METHODS

The material was preserved in 4% formalin.

Slides were made by mounting a sample droplet in a drop of glycerine.

Drawings were made with a Zeiss binocular bright field/phase contrast microscope using a Leitz micrometer-net-ocular and specially printed squared paper, the squares being 2×2 cm. The lenses used were a 12,5× eye-piece and a 40× objective.

Photomicrographs were taken on Adox KB14 film using a 35 mm Willd microscope camera on a Zeiss Nomarski contrast microscope. A 6× eye-piece and a 40× objective were used.

All dimensions are given in micrometres (μm).

OBSERVATIONS AND DISCUSSION

The following taxa were identified in the sample collected by Schweickerdt:

1. **Micrasterias ambadiensis** (*Grönblad & Scott*) *Thomasson* (1960, p. 22, Figs 4: 10 & 10: 4; Lind, 1971, p. 542, Pl. 2, Fig. 3).

Syn.: *M. radians* Turner var. *ambadiensis* Grönblad & Scott (Grönblad, Prowse & Scott, 1958, p.21, Pl. 11, Fig. 119 & Pl. 26, Fig. 363; Grönblad, 1962, p.7, Pl. 1, Fig. 9).

Some variation with regard to the delineation of the lateral lobes occurred in the Rusape specimens (Figs 11–14 and 26–29). In the type figures by Grönblad & Scott (1958, Figs 119 and 363) as well as Thomasson's figure (1960, Fig. 4: 10) the inferior lateral lobes have three spines each and the superior lateral lobes either three or four. In the specimen depicted in Grönblad's Fig. 9 (1962) both inferior and superior lateral lobes have four spines each and in Lind's specimen (1971, Pl. 2, Fig. 3) both inferior and superior lateral lobes have three spines each. In the Rusape specimens the number of spines in both inferior and superior lateral lobes varies from two to four. In a single specimen one inferior lateral lobe was completely absent and another consisted of a single spine (Fig. 12, bottom semicell). An abnormal coalescence of the cell wall in the inner portion of the sinus was observed in another specimen (Fig. 26). This specimen also showed abnormal cell wall thickenings at the base of each incision between the inferior and superior lateral lobes and between the superior lateral lobes and the polar lobe (upper semicell) as well as a large granule in the centre of the apical margin of the polar lobe. Length without spines 114–136, with spines 140–168; width without spines 98–113, with spines 112–131; width of isthmus 23–24; maximum width of polar lobe without spines 44–48, with spines 60–72. Very common.

2. **Micrasterias crux-melitensis** (*Ehrenberg*) *Hassall* forma **minor** *Turner* (1892, p. 92, Pl. 5, Fig. 4c; Grönblad, Prowse & Scott, 1958, p. 19, Pl. 11, Fig. 124 & Pl. 25, Fig. 358; Hinode, 1969, p. 199, Fig. 7: 11; Krieger, 1939, p. 65, Pl. 115, Fig. 1).

In some of the Rusape specimens the basal portion of the polar lobe is noticeably broader than in the typical form (Fig. 15). Length without spines 74–76, with spines 87–89; width without spines 80–82, with spines 86–89; width of isthmus 15–17; maximum width of polar lobe 42–44. Rare.

3. **Micrasterias decemdentata** (*Nägeli*) *Archer* (Borge, 1918, p. 66, Pl. 5, Fig. 23; Grönbald & Croasdale, 1971, p. 11, Pl. 4, Fig. 47; Grönblad, Scott & Croasdale, 1964, p. 15, Pl. 9, Fig. 219; Krieger, 1939, p. 34, Pl. 104, Figs 9–11; Lind, 1971, p. 542, Pl. 1, Fig. 29).

Syn.: *M. decemdentata* (Näg.) Arch. var. *galpinii* Claassen, 1961, p. 585, Pl. 17, Figs 4–7.

Specimens with 10 spines per semicell were rather rare; more common were specimens with 6 (Figs 16 and 17, upper semicells) or 9 (Fig. 17, lower semicell) spines per semicell. Fig. 16 represents a specimen in which one of the polar lobes is undeveloped (lower semicell). Length 47,5–50; width without spines 46–50, with spines 56,5–62; width of isthmus 10–12; maximum width of polar lobe without spines 30–31, with spines 36–40,6. Rare.

* Department of Botany, University of Pretoria, Pretoria.

4. **Micrasterias pinnatifida** (*Kützing*) *Ralfs* var. **incudiformis** *West & West* (1895, p. 48, Pl. 6, Fig. 5; Grönblad & Croasdale, 1971, p. 11, Pl. 4, Fig. 49; Krieger, 1939, p. 19, Pl. 100, Fig. 3).

These specimens (Figs 18–21) more closely resemble the plant represented in Grönblad & Croasdale's Fig. 49 than the type specimen but their dimensions agree better with that of the type. Length 56–60; width without spines 57–62, with spines 61–67; width of isthmus 11–12; maximum width of polar lobe without spines 38–46,8, with spines 44–52. Very common.

5. **Micrasterias radiata** *Hassall* var. **brasiliensis** *Grönblad* sensu lato, 1945, p. 15, Pl. 4, Figs 82 & 83; Förster, 1969, p. 41, Pl. 11, Fig. 5 & Pl. 12, Fig. 1; Thomasson, 1960, p. 24, Figs 4: 8 & 6: 12.

Syn.: *M. radiata* Hassall pro parte, in Krieger, 1939, p. 68, Pl. 117, Fig. 4 (non Pl. 116, Figs 4–6 & Pl. 117, Figs 1–3); *M. radiata* Hassall forma Nordstedt (1869, in Borge, 1925, p. 29, Pl. 2, Fig. 7) in Förster, 1974, p. 156; *M. radiata* Hassall var. *groenbladii* sensu Förster, 1974, p. 156, Pl. 7, Fig. 1 (non Pl. 5, Fig. 80 in Scott, Grönblad & Croasdale, 1965); *M. radians* Turner var. *brasiliensis* (Grönblad) Krieger in Förster, 1964, p. 380, Pl. 18, Figs 1 & 2; Krieger & Scott (1957, p. 135) in Förster, 1974, p. 156.

The plant referred to here and all the cited figures seen by the present author more closely resemble Grönblad's Fig. 83 than his Fig. 82. A broad interpretation of *M. radiata* var. *brasiliensis* has been adopted because, as the following discussion reveals, there is no name available for the plant illustrated in Fig. 83, and it is felt that, in view of the rather confused nomenclature, it would be unwise to describe a new taxon at this stage.

When Grönblad (1945) created *M. radiata* var. *brasiliensis* he illustrated it with two figures. In his Explanation of Plates he said "Fig. 82 is the most frequent form, Fig. 83 is a larger form with more slender processes" (Scott, Grönblad & Croasdale, 1965, p. 40). Croasdale (Scott, Grönblad & Croasdale, 1965) felt that the plant represented in Grönblad's Fig. 83 should be distinguished from the plant represented in Fig. 82. She included this plant (Fig. 83) in the new variety *M. radiata* var. *groenbladii* Croasdale (Scott, Grönblad & Croasdale, 1965, p. 39, Pl. 5, Fig. 80) and thereby it could possibly be construed that she indirectly made Grönblad's Fig. 82 the lectotype of *M. radiata* var. *brasiliensis*. As Croasdale failed to indicate a type, the name *M. radiata* var. *groenbladii* was not validly published (Stafleu, 1972, p. 41, Art. 37). Förster (1969, p. 41) decided that the plants depicted in Grönblad's Fig. 83 and Croasdale's Fig. 80 represented different varieties. He transferred the plant represented in Grönblad's Fig. 83 back to *M. radiata* var. *brasiliensis* and incorporated the plant represented in Croasdale's Fig. 80 in his new variety *M. radiata* var. *croasdaleae* Förster (1969, p. 41, Pl. 12, Fig. 2) as a synonym. The name *M. radiata* var. *croasdaleae* was also not validly published as no type was indicated, although Förster mentioned on the first page of his paper where slides containing new described taxa are preserved.

When Förster (1969, p. 41) discussed *M. radiata* var. *brasiliensis* he cited only Grönblad's Fig. 83 and not Fig. 82 and it is not clear whether he meant that his plant was *M. radiata* var. *brasiliensis* Grönblad, pro parte, quoad Fig. 83.

Later Croasdale (Grönblad & Croasdale, 1971, p. 40) indicated her Fig. 80 in Scott, Grönblad & Croasdale, 1965, as the type for *M. radiata* var. *groenbladii* Croasdale. This validated the publication of the variety and means that the name *M. radiata* var. *croasdaleae* Förster is superfluous and illegitimate and Förster's concept of *M. radiata* var. *groenbladii* Croasdale in Förster, 1974, p. 156, is incorrect. When Förster (1974, p. 156) recognized Croasdale's variety *groenbladii*, he excluded Fig. 80 and cited Grönblad's var. *brasiliensis*, pro parte, quoad Fig. 83 as one of the synonyms. Thomasson (1960, p. 24, Figs. 4: 8 and 6: 12) recorded *M. radiata* var. *brasiliensis* Grönblad, 1945, cf. Fig. 83 for Lake Bangweulu and although this paper appears in Förster's list of references (1974, p. 195) Thomasson's figures were not cited amongst the above-mentioned synonyms.

Fig. 24 of the Rusape specimens resembles Thomasson's Fig. 4: 8 (1960, p. 15) and Fig. 9 resembles Thomasson's Fig. 6: 12 (1960, p. 19) and Förster's Pl. 7, Fig. 1 (1974, p. 213).

In the Rusape specimens there is a noticeable variation in the width of the basal portions of the polar lobes of mature semicells (Figs 9, 10, 24 and 25). An abnormal coalescence of the cell wall was observed in the inner portion of the sinus (Fig. 24) between the superior lateral and polar lobes (Fig. 24) and between the lobules of the inferior and superior lateral lobes (Fig. 25, mature semicell). The latter also showed abnormal cell wall thickenings in the diverging processes of the polar lobe. Length with spines 180–208; width with spines 138–150; width of isthmus 20–22; maximum width of polar lobe 80–100. Common.

6. **Micrasterias schweickerdtii** *Claassen,* sp. nov. (Figs. 1–8).

DIAGNOSIS

Inter species descriptas nulla affinitas obvia. Cellulae amplae circiter 1,2–1,3-plo longiores quam latiores, ellipticae, penitus constrictae, sinus apertus; semicellulae trilobae. Lobus polaris magnus, subcuneatus, anguli laterales deorsum curvati, apex incisura mediana signatus, margini apicis spinae sunt plerumque curvatae, 6 vel 7 utrimque ab incisura mediana. Lobi laterales incisuris non profundis in lobulos quattuor inaequales divisi; lobulus superior sursum curvatus, tribus vel quattuor spinis marginalibus ac curvatis instructus; quarum ima maxima, vel in formam lobuli parvi et bidenticulati delineata; lobuli mediani aut binis spinis marginalibus instricti, aut in binos lobulos minores et bidenticulatos subdivisi, aut ex singula spina magna et lobulo parvo et bidenticulatu constant; lobulus inferior deorsum curvatus, tribus, spinis marginalibus instructus. Cellulae paries porosus, plurimis instructus spinis quae in series subradiatas in lobis polaribus et lateralibus sunt dispositae; modo aliquot spinae in semicellula media admodum supra isthmum inveniuntur, modo nullae. Longitudo sine spinis 256–307 μm, cum spinis 284–337 μm; latitudo sine spinis 201–234 μm, cum spinis 227–262 μm; isthmi latitudo 41–45,5 μm; lobi polaris latitudo maxima sine spinis 124–146 μm, cum spinis 139–161 μm. Iconotypus: fig. mihi 5.

This species does not correspond to any other *Micrasterias* in literature available to the author.

Cells large, about 1,2–1,3 times longer than broad, elliptic, deeply constricted, sinus open; semicells 3-lobed. Polar lobe large, subcuneate, lateral angles curved downwards, apex with a median notch, apical margin with 6–7, generally curved, spines on each side of the median notch. Lateral lobes divided into 4 unequal lobules by shallow incisions; superior lobule curved upwards, furnished with 3–4

marginal curved spines, lowermost spine largest or delineated as a small 2-denticulate lobule; median lobules furnished with 2 marginal spines each or subdivided into 2 smaller 2-denticulate lobules or consists of one large spine and a small 2-denticulate lobule; inferior lobule curved downwards, furnished with 3 marginal curved spines. Cell wall porose, furnished with numerous spines arranged in subradiate rows within the polar and lateral lobes, with or without a few spines in die middle of each semicell just above the isthmus. Length without spines 256–307, with spines 284–337; width without spines 201–234, with spines 227–262; width of isthmus 41–45,5; maximum width of polar lobe without spines 124–146, with spines 139–161. Very rare.

Several unsuccessful attempts were made to turn the cells over, so that they could be studied in lateral or apical views.

The specimen depicted in Figs 3, 4 and 8 was slightly anomalous in that one side of the sinus was linear and not open.

7. **Micrasterias tropica** *Nordstedt* var. **tropica** (Krieger, 1939, p. 56, Pl. 112, Fig. 4).

In the polar lobes of the Rusape specimens (Figs 22, 23, 30 and 31) the diverging processes are longer than in the type. These specimens fall rather in between the plants represented in Krieger's Fig. 4 (1939, Pl. 112) and his Fig. 7 (1939, Pl. 113) for *M. tropica* var. *elegans* West & West as the lateral and polar lobes are more slender than in the typical variety and less slender than in var. *elegans*. The semicell depicted in Fig. 23 could be compared with var. *elegans* but for the shorter polar lobe. Length 92–104; width 80–106; width of isthmus 14–17,7; maximum width of polar lobe 58–63,5. Rare.

ACKNOWLEDGEMENTS

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UITTREKSEL

Micrasterias ambadiensis (*Grönblad & Scott*) *Thomasson*, M. crux-melitensis (*Ehrenberg*) *Hassal forma* minor *Turner*, *M.* decemdentata (*Nägeli*) *Archer*, M. pinnatifida (*Kützing*) *Ralfs var.* incudiformis *West & West*, M. radiata *Hassall var.* brasiliensis *Grönblad sensu lato, en* M. tropica *Nordstedt var.* tropica *word bespreek. 'n Nuwe spesie,* M. **schweickerdtii** *Claassen,* word beskryf.

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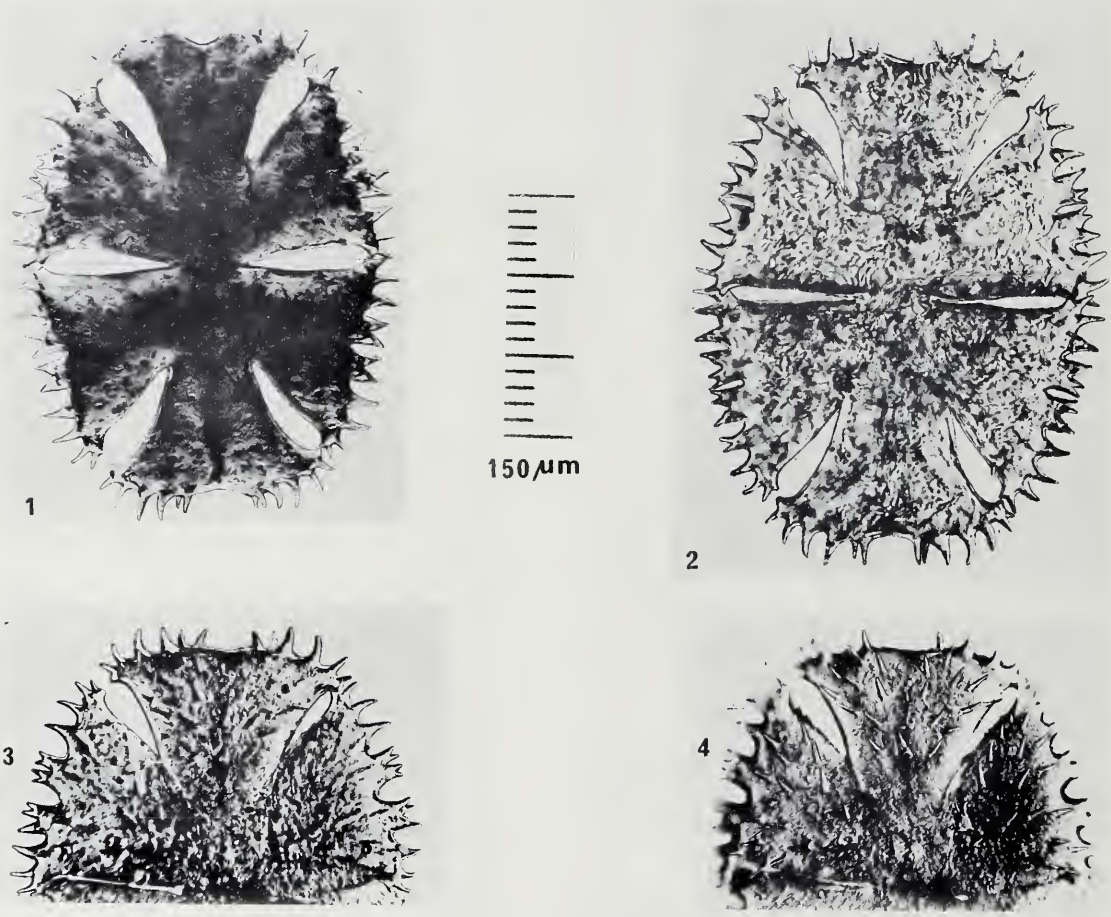
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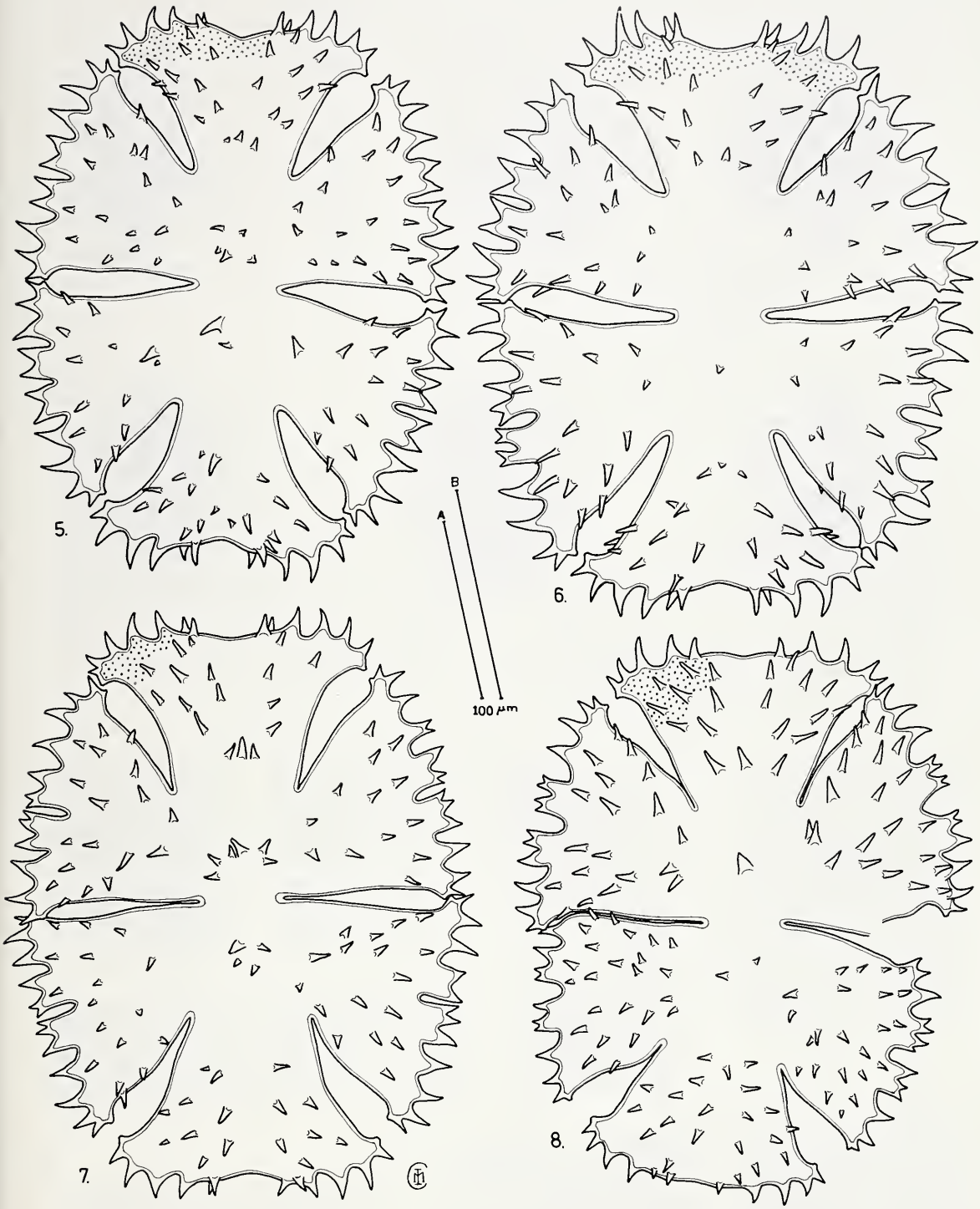
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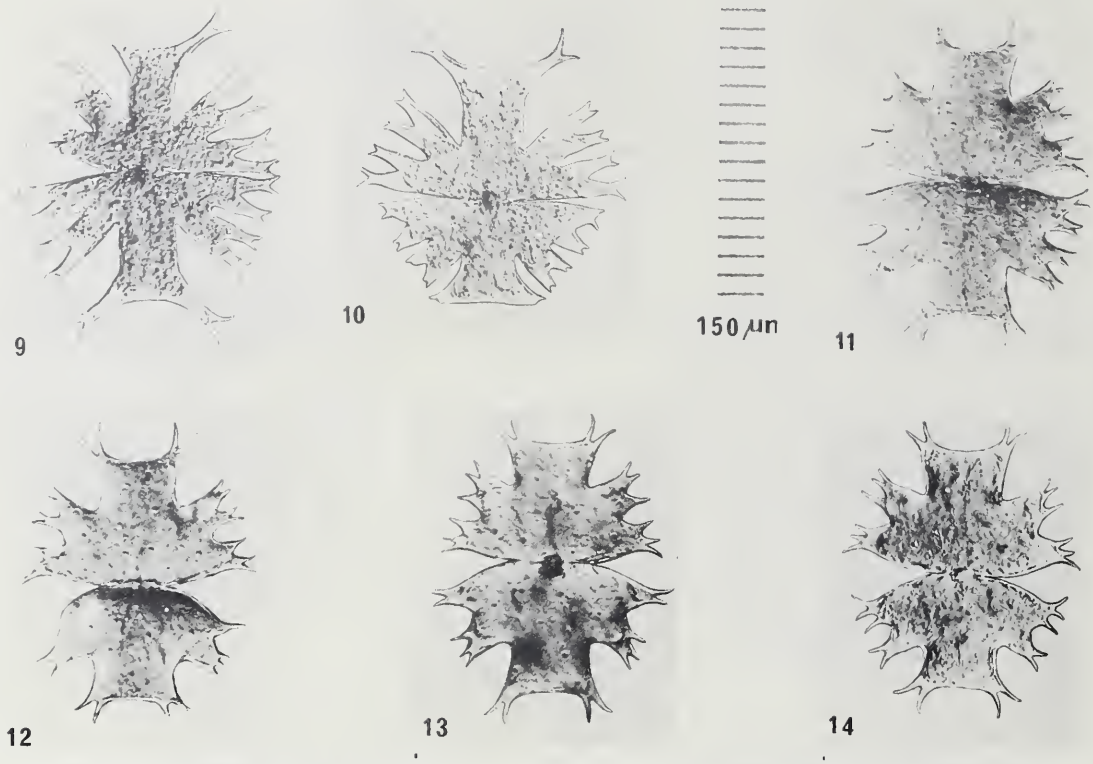
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FIGS 1–4.—*Micrasterias schweickerdtii*; 4, semicell showing spines in surface view.



FIGS 5–8.—*Micrasterias schweickerdtii.*



FIGS 9, 10.—*Micrasterias radiata* var. *brasiliensis*; 9, mature cell; 10, cell in divisional stage. 11–14, *M. ambadiensis*, various specimens showing variation of lateral lobes.

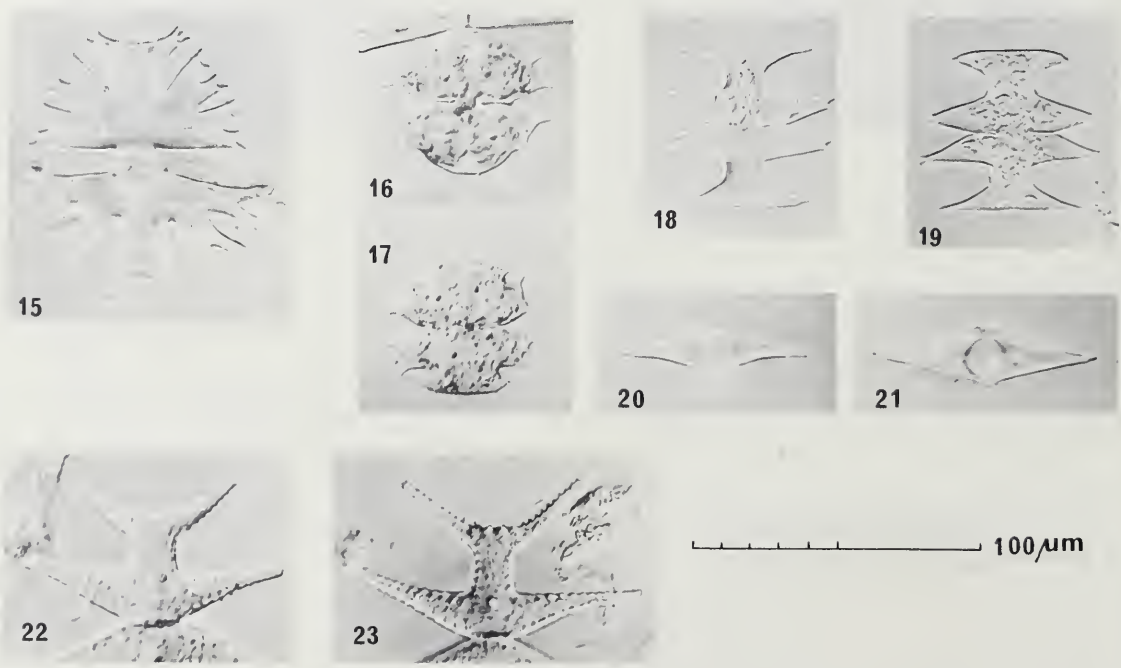


FIG. 15.—*Micrasterias crux-melitensis* forma *minor*. 16, 17, *M. decemdentata*. 18–21, *M. pinnatifida* var. *incudiformis*; 18, 19, front view of cell; 20, apical view of semicell; 21, basal view of semicell. 22, 23, *M. tropica* var. *tropica*.



FIGS 24, 25.—*Micrasterias radiata* var *brasiliensis*; 24, mature cell; 25, cell after division with anomalous upper semicell. 26–29, *M. ambadiensis*, various specimens showing variation of lateral lobes. 30, 31, *M. tropica* var. *tropica*.

Bothalia 12, 2: 247–250 (1977)

Asexual nuclear division in *Neocosmospora**

K. T. VAN WARMELO†

ABSTRACT

A fungus isolated from soybean stem material showed marked similarities to two existing species of *Neocosmospora*, i.e. *N. vasinfecta* E. F. Smith and *N. africana* von Arx. The processes of somatic nuclear division in authentic cultures of these two species and the new isolate were examined to determine the nature of the mechanism of nuclear division and whether there were any differences among the cultures. No significant differences were observed. The divisions showed asynchronous anaphase disjunction but there was no evidence of aneuploidy or irregular reconstitution of daughter nuclei. Nuclear division was interpreted as being strictly mitotic.

RESUME

CARYOCINESE ASEXUEE CHEZ NEOCOSMOSPORA

Une moisissure isolée de tiges de soya a montré des ressemblances marquées avec deux espèces existantes de Neocosmospora, *soit* N. vasinfecta *E. F. Smith et* N. africana *von Arx. Les processus de caryocinèse somatique ont été examinés dans des cultures authentiques de ces deux espèces et dans le nouvel isolat pour déterminer la nature du mécanisme caryocinétique et noter les différences entre cultures s'il y en a. On n'a pas observé de différences significatives. Les divisions ont montré une dislonction asynchrone à l'anaphase, mais il n'y avait aucun signe d'aneuploïdie ou de reconstitution irrégulière de noyaux-fils. La caryocinèse a été interprétée comme étant strictement mitotique.*

REVIEW

Reported mechanisms of somatic nuclear division in the fungi seem to fall into two basic categories, i.e. divisions which are essentially mitotic, differing only slightly from the classical concept, and non-mitotic divisions in which completely different processes are operative.

Divisions in a large variety of fungi were shown to differ from mitosis in higher plants only in that the nuclear membrane was persistent throughout the division (Thyagarajan, Conti & Naylor, 1962; Moor, 1966; Robinow & Marak, 1966; Heath & Greenwood, 1968; McManus & Roth, 1968; Aist, 1969; Aldrich, 1969; van Winkle, Biesele & Wagner, 1971). The spindle was thus fully intranuclear (Ichida & Fuller, 1968; Motta, 1969; Zickler, 1970).

Persistence of the nuclear membrane was, however, not an invariable condition, as fungi were reported in which the membrane broke down during division (Robinow, 1963; Namboodiri & Lowry, 1967; Motta, 1969; Brushaber & Jenkins, 1971).

An additional difference between somatic divisions in fungi and higher plants was the variable presence of centrioles. Several fungi, representative of widely differing taxonomic groups, were reported as lacking centrioles (Namboodiri & Lowry, 1967; McManus & Roth, 1968; Aldrich, 1969) whereas their presence was demonstrated in others (Moor, 1966; Robinow & Marak, 1966; Brushaber & Jenkins, 1971; van Winkle *et al.*, 1971).

Despite the differences referred to above, however, the divisions in a large number of fungi have been described as essentially mitotic (Robinow, 1963; Hosford & Gries, 1966; Knox-Davies, 1966, 1967; Finley, 1970; Brushaber & Jenkins, 1971, van Warmelo, 1971).

The actual arrangement of chromosomes immediately prior to, and during, separation has been the subject of intensive investigation and a large number of different mechanisms of chromosomal separation have been proposed as a result.

The formation of typical metaphase plates was reported (Robinow, 1963; Finley, 1970) and also the separation of discrete chromatids on a well-defined spindle (Knox-Davies, 1966, 1967; Ichida & Fuller, 1968; McManus & Roth, 1968; Motta, 1969; Brushaber & Jenkins, 1971). Aist (1969), however, maintained that instead of forming a true metaphase plate the chromosomes became attached to the spindle at different points. During anaphase separation the chromatids thus became strung out on the spindle.

Instead of separate chromosomes, the presence of a single coherent strand, formed by the linked chromosomes has been reported (Weijer, Koopmans & Weijer, 1965; Dowding, 1966; Weijer & Weisberg, 1966; Brushaber, Wilson & Aist, 1967; Laane, 1967; Namboodiri & Lowry, 1967; Heale, Gafoor & Rajasingham, 1968; Brushaber & Jenkins, 1971). The single nuclear strand is thought to replicate to form a double strand which then separates in a number of ways. Movement of each replicated strand on a well defined spindle was reported by Heale *et al.* (1968). Spindles were, however, apparently absent in the other fungi showing filamentous nuclei. Shearing of chromatids by cytoplasmic streaming was suggested by Weijer *et al.* (1965) but, whereas this proposal received some support (Laane, 1967), it has not been generally accepted. In the absence of a spindle the exact mechanism of chromatid disjunction and movement is not yet fully understood.

Judging from the conflicting descriptions given above it seems possible, as suggested by Bracker (1967), that there may be a number of mechanisms of somatic nuclear division in the fungi, instead of one common process.

MATERIALS AND METHODS

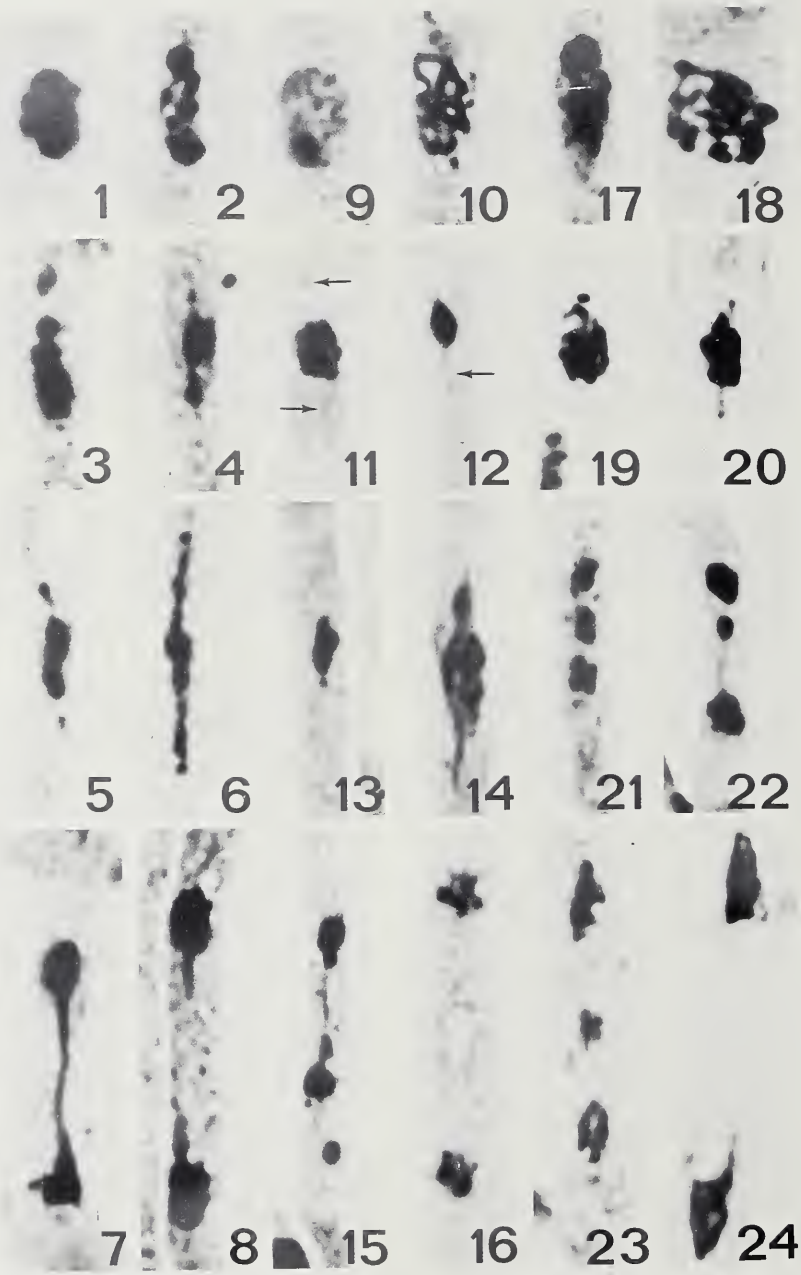
Three cultures were examined in this investigation:

1. *Neocosmospora vasinfecta* E. F. Smith; CBS 237.75.
2. *Neocosmospora africana* von Arx; CBS 237.
3. *Neocosmospora* sp. isolated from soybean stem, Pietermaritzburg, South Africa. Referred to in the following text as "isolate P."

Somatic divisions were studied using the macerated mycelium technique described by Ward & Ciurysek (1962). After being stained using the HCl-Giemsa technique (van Warmelo, 1971) the hyphae were flattened under a coverglass which was then sealed with paraffin oil.

* Based on a Ph.D. (Agric.) thesis submitted to the University of Stellenbosch, 1973. Promoter: Prof. P. S. Knox-Davies, Ph.D. (Wis.).

† Rand Afrikaans University, P.O. Box 524, Johannesburg.



FIGS 1–8.—Mitosis in *Neocosmospora vasinfecta*, ×3000. 1, early prophase; 2, prophase with clearly visible chromosomes; 3, late prophase with short chromosomes; 4, mid metaphase with six distinguishable chromosomes; 5, metaphase/anaphase; 6, mid anaphase showing chromosomes between clearly visible centriolar plaques; 7, early telophase with spindle bridge apparently enclosed within nuclear membrane; 8, early telophase.

FIGS 9–16.—Mitosis in *Neocosmospora africana*, ×3000. 9, early prophase with visible chromosomes; 10, prophase; 11, prometaphase in polar view with visible centriolar plaques (arrowed); 12, very early metaphase with forming spindle (arrowed); 13, early metaphase; 14, anaphase; 15, early telophase with spindle bridge; 16, telophase.

FIGS 17–24.—Mitosis in *Neocosmospora* isolate P, ×3000. 17, early prophase with visible chromosomes and nuclear membrane; 18, prophase in large hypha with clearly visible chromosomes; 19, prophase with shortened chromosomes; 20, mid metaphase with formed spindle; 21, early anaphase; 22, late anaphase with chromosome disjunction almost completed; 23, late anaphase showing residual interzonal fibres; 24, late telophase.

RESULTS

As the mechanisms of somatic division in the three cultures did not show any significant differences, the processes of division will not be described separately. Individual isolates will be highlighted only where necessary.

The interphase nuclei were large and typical. The onset of prophase was shown by the delimitation of chromosomes within the nuclei (Figs 1, 9 and 17). Initially long and thin, the chromosomes were shorter and more distinct at mid-prophase (Figs 2, 10 and 18). Nucleoli which were clearly distinguishable at early prophase, were usually absent at mid-prophase. The size of the somatic cell appeared to affect the size of the nucleus. In isolate P (Fig. 18) cells of large diameter were found in which the nuclei were much larger, and the chromosomes much clearer, than in the more common narrow hyphae. At late prophase the chromosomes were appreciably shorter than at early prophase, but could not be counted (Figs 3 and 19). Occasional persistent nucleoli were seen at this stage.

At prometaphase (Fig. 11) centriolar plaques were sometimes distinguishable.

During early metaphase the chromosomes had condensed further and were shorter than at late prophase (Fig. 12). At metaphase they were situated midway between the two centriolar plaques and incipient spindles were observed (Figs 12 and 13). At mid-metaphase the spindle was clearly distinguishable (Figs 5 and 20).

Occasionally individual chromosomes were distinguished at metaphase (Figs 4 and 20) and a count at this stage gave an estimated number of six.

Anaphase was a variable stage and chromosome separation appeared to be asynchronous, as a variety of nuclear figures were found (Figs 6, 14, 21 and 22). At late anaphase the interzonal fibres between the terminal chromosome aggregations were occasionally observed (Fig. 23).

At early telophase the two daughter nuclei became reconstituted but were frequently connected by a chromosome or spindle bridge (Figs 7 and 15) apparently still enclosed within the nuclear membrane. The bridge then broke and shortened (Fig. 8). The divisions thus appear to be entirely intra-nuclear.

Mid- and late-telophase nuclei (Fig. 16) were dense and smaller than post-division interphase nuclei (Fig. 24) which were identical with pre-division interphase nuclei.

At no stage were nuclear strands observed or stages seen which would have suggested linking-up of individual chromosomes.

DISCUSSION

No significant differences in nuclear division were found to occur in these three cultures. This agrees with their close similarity in other respects.

Due to the small diameter of most somatic hyphae there is probably insufficient space available for the formation of a typical metaphase plate, as found in higher organisms, and for the simultaneous disjunction and movement of chromatids on the spindle. The only mechanism which would ensure an equal distribution of chromatids under such conditions would be a sequential or asynchronous separation. Pairs of chromatids would then separate and move away from the central spindle area before separation of the next chromatid pair, thus ensuring non-interference by non-sister chromatids destined for different daughter nuclei.

Although anaphase separation was asynchronous there was no evidence of irregular chromosome disjunction or aneuploidy. This was deduced from the absence of lagging chromosomes or fragments at late telophase or interphase, indicating complete reconstitution of daughter nuclei, the constancy of chromosome numbers and the phenotypic stability of the cultures.

The consistent presence of observably separate chromosomes during nuclear division, coupled with the absence of stages showing linking of chromosomes, indicates that somatic nuclear division in *Neocosmospora* can be interpreted as strictly mitotic.

ACKNOWLEDGEMENTS

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UITTREKSEL

'n Swamsoort afkomstig van sojaboon weefsel het duidelike ooreenkomstes getoon met twee bestaande Neocosmospora *soorte, nl.* N. vasinfecta *E. F. Smith en* N. africana *von Arx. Die somatiese kerndelingsprosesse in outentieke kulture van hierdie twee organismes en in die nuwe isolaat is ondersoek om vas te stel wat die delingsmeganismes was en of daar verskille tussen die kulture aanwesig was. Geen wesenlike verskille tussen die kulture is opgemerk nie. Die delings het asinkroniese anafaseskeidings getoon maar daar was geen tekens van aneuploiedie of onreëlmatige vorming van die dogterkerne nie. Die meganisme van kerndeling is suiwer mitoties.*

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Bothalia 12,2: 251–259 (1977)

Notes on African plants

VARIOUS AUTHORS

ARACEAE

A NEW SPECIES OF *GONATOPUS* FROM SOUTHERN AFRICA

Gonatopus rhizomatosus *Bogner & Oberm.* sp. nov., *G. boivinii* (Decne.) Engl. affinis, sed rhizomate cylindraceo longo horizontali non globoso et petiolo non geniculato differt.

Planta rhizomatosa 20–40 cm alta. *Folium* unum annuum decompositum proteranthum; petiolus tenuis 15–25 cm longus; lamina a basi ternata supra 1–2 divisa; pinnae oppositae vel suboppositae decurrentes. *Spadix* breve pedunculata c. 10 cm longa. *Spatha* angusta c. 7 cm longa margine ad basi libero. *Flores masculi* superiores; tepala paribus oppositis semi-prismatica truncata 3 mm longa. *Staminum filamenta* connata. *Flores steriles* in medio masculini et feminei. *Flores feminei* inferiores. *Gynoecium* ampulliformum bilocularum; ovulum anatropum. *Bacca* oblongo-globosa c. 15 mm longa; semen anguste ellipsoideum, 12 mm longum.

TYPE: Transvaal, 2531 (Komatipoort): 5 km S. of Kaalrug Police Station near Swedish Mission (–DA), *Codd 7814* (PRE, holo.; M, iso.).

Herbaceous plant producing annually one leaf and later beside it 1 or rarely 2 inflorescences. *Rhizome* horizontal, 20 cm long and 3 cm in diameter, or longer, cylindrical, tuberous, somewhat contracted irregularly at intervals, forming much-branched mats, brown outside with white flesh; roots scattered, fairly thick.



FIG. 1.—*Gonatopus rhizomatosus.* Eastern Transvaal (*Codd* 7814), ×½.

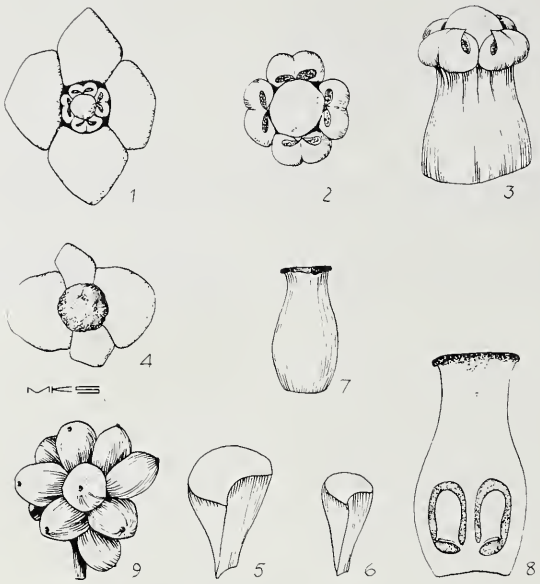


FIG. 2.—*Gonatopus rhizomatosus*. 1, male perianth, ×6; 2, stamens and sterile ovary from above, ×10; 3, stamens seen from side, ×10; 4, female perianth, ×6; 5, outer tepal × 6; 6, inner tepal × 6; 7, ovary, × 6; 8, longitudinal section through ovary, ×10; 9, fruits, ×½. (*Moll* 4974A).



FIG. 3.—Pollen grains (×500) of *Gonatopus rhizomatosus* Photo: W. Barthlott.

Leaf erect, with a petiole 15–25 cm long, dull grey with lighter mottling, surrounded by cataphylls at the base; lamina somewhat fleshy, decompound, 3-branched at the base, once or twice branched above it, pinnae opposite or subopposite, linear to oblong, attenuate above and below, 4–8 cm long, all or only the terminal decurrent on rhachis, often with a small side-lobe. *Spadix* on a short peduncle c. 10 cm long, grey, mottled; spathe constricted, green in bud, turning pinkish buff with black stripes but soon drying up, c. 7 cm long, closely enveloping spadix, apiculate, not fused below, the upper part reflexed at anthesis, the lower enclosing the female part for some time, dropping off when fruit is set. *Male flowers* compressed in spiral series on upper half of cylindrical, obtuse spadix; tepals in 2 opposing free pairs, semi-prismatic, thick, truncate, c. 3 mm long; stamens 4, with the filaments fused into a tube, surrounding the sterile, clavate gynoecium; anthers arranged in a circle, thecae opening apically towards the centre. *Pollen grains* depressed globular, 95–110μ×30–40μ, meridionosulcate, exine sparsely covered with very small foveolae. *Female flowers* on lower part of spadix, with sterile flowers in between male and female flowers; tepals similar to male flowers; stamens absent; gynoecium flask-shaped, laterally compressed, 2-locular with an anatropous basal ovule in each locule; style short; stigma discoid, large, green, just protruding from perigon. *Berries* bilocular, oblong-globose, c. 15 mm long, in a globose cluster surrounded basally by the persistent tepals and unfertilized flowers, walls soft, thin. *Seed* narrowly ellipsoid, 12 mm long, coat thin, without endosperm. Chromosomes: 2n=c.68 (N. Jacobsen). Figs 1, 2 & 3.

Eastern Transvaal, northern Natal, Mozambique, Rhodesia; common in undergrowth of dune forest in northern Natal, often in shady rock pockets in low-lying bushveld areas of eastern Transvaal; flowering November to February.

Transvaal.—2331 (Phalaborwa): Gorge (–DD), *Van der Schijff 2387*. 2431 (Acornhoek): 21 km E. of Skukuza (–DC), *Codd 5045*. 2531 (Komatipoort): 4 km W. of Lower Sabie Camp (–BB), *Codd 5707* (M, PRE); Kaap Muiden (–CB), *Mogg 13687*; 5 km S. of Kaalrug Police Station near Swedish Mission (–DA), *Codd 7814* (PRE, holo.; M, iso.).

Natal.—2632 (Bela Vista): Mtombeni Forest, slopes facing Nhlange Lake (–CD), *Tinley 396*. 2731 (Louwsburg): Josini Dam, slopes (–BD), *Strey 5278*. 2732 (Ubombo): Ngwavuma, on road to Ndumu (–AA), *Venter 5215*; Lebombo foot hills on road to Pongola River (–AC), *Strey 6580*; Makatini flats near Mbazwane (–BC), *Vahrmeijer & Toelken 208*. 2831 (Nkandla): Umfolozi Game Reserve (–BD), *White 10357*; 16 km W. of Empangeni on Melmoth Road (–DD), *Moll 4974a*. 2832 (Mtubatuba): Hluhluwe Game Reserve (–AA), *Ward 1967*; near Mtubatuba (–AC), *Codd 9619*.

Mozambique.—Inhaca Island, *M. Moss sub. J. 28428*.

Rhodesia.—Beitbridge district, 16 km S. of Lundi River, *Wild 7610*.

Two species of *Gonatopus* occur in southern Africa, namely *G. boivinii* (Decne.) Engl., a tropical eastern African species, which reaches its southernmost limit in northern Natal, and *G. rhizomatosus*, the species here described, which has been recorded from northern Natal, eastern Transvaal Lowveld, Mozambique and Rhodesia.

In *G. boivinii*, a taller plant, the underground part consists of a globose often depressed tuber, the petiole forms a swollen articulation in the middle and the decompound lamina has sessile or petiolate paired pinnae, which are not decurrent. In *G. rhizomatosus* the underground part consists of a long horizontal tuberous rhizome, the petiole is without a swollen central articulation and the decompound lamina has the pinnae opposite or subopposite and decurrent. There is also a difference in the size of the pollen grains for they are much larger than those of *G. boivinii* and the exine is more sparsely covered withf oveolae.

Mr Josef Bogner of the Botanical Garden of Munich, co-author of *G. rhizomatosus*, is an authority on the Araceae. He assisted me most generously in clarifying the position of this species and the tropical ones described by A. Peter under the latter's genus *Microculcas*. Mr Bogner will deal with these taxonomic problems at a future date. He assures me that our southern rhizomatous species differs from *Microculcas marattioides* described by Peter from Tanzania. The latter also possesses a horizontal rhizome but, in addition, develops long stolons which swell up to about the thickness of a finger and produce a leaf at their ends. The petiole too, is swollen basally, but becomes attenuated and thin above.

A. A. Obermeyer

ASCLEPIADACEAE

A NEW SPECIES OF *CARALLUMA* FROM THE CAPE

Caralluma multiflora *R. A. Dyer* sp. nov., *C. mammilliari* (L.f.) N.E. Br. affinis, corolla alabastro plusminusve oblonga, obtusa; corollae lobis replicatis carinatis, plusminusve oblongis, apicem versus incurvis, carina infra medium et fauce dense papillosis distinguitur.

Planta carnosa ramosa, usque ad 15 cm alta; caules 4–5-angulati, circiter 2 cm crassi, tuberculati; tubercula triangulata, 6–7 mm prominentia, apicem versus indurata, acuta. *Flores* multi, fasciculati. *Corolla* alabastro plusminusve oblonga, obtusa, 5-angulata, circiter 1,5 cm longa, glabra, atropurpurea, breviter tubulata; tubus campanulatus, circiter 4 mm longus, intus pallidus, sparse pubescens et maculatus; faux dense papillosa; lobi plusminusve oblongi, erectopatentes, apicem versus incurvi, replicati, carinati; carina infra medium papillosa. *Corona* breviter campanulata; lobi exteriores suberecti, profunde bifidi, dentibus 0,5 mm longis; lobi nteriores incumbenti-erecti, basi in lobulum subquadratum vel ovatum producti. *Pollinia* circiter 0,25 mm longa. *Folliculi* 2 (1), 13–14 cm longi, 7–8 mm diam, longistrorsum maculati.

Type.—Cape, 3119 (Calvinia): Kareeboomfontein, west of Rebunie (–DA) 17th October 1975, *W. J. Hanekom 2475* (PRE, holo.).

Succulent plant up to about 15 cm tall, freely branching and rooting from the basal branches; branches 4–5-angled, prominently tuberculate along the angles, with a spread of 2,5–2,75 cm, bluish-green to purplish red-brown; tubercles triangular in side view, spreading 6–7 mm, with a sharp hard apex. *Flowers* mainly from flowering eyes towards the apex of branches between or along the angles, in fascicles of up to 12 flowers together, opening more or less together; pedicels 4–5 mm long. *Sepals* linear-lanceolate, about 3 mm long. *Corolla* in bud more or less oblong in outline, but broadest slightly above middle, 5-angled, 1,5 cm long, glabrous outside, dark maroon to black with short yellowish-green to light

coloured tube; tube campanulate, about 4 mm long, with scattered hairs within and maroon-marked, densely papillate round mouth of tube; papillae with acute apex bent at right-angles; lobes more or less oblong in outline, suberect, with incurving tips and recurving margins, obtusely keeled down inner face, with few papillae down keel towards base. *Corona* shortly cup-shaped or campanulate at base; outer lobes deeply bifid and alternating with spreading basal lobule of inner corona-lobes, teeth of outer lobes about 0,5 mm long, suberect; inner corona-lobes about 2 mm long, incumbent-erect into a cone-shaped apex above the staminal column, with a spreading ovate or subquadrate basal lobe (variable) alternating with the outer corona-lobes and about the same length. *Pollinia* about 0,25 mm long with very short weak connectives; carrier very shortly winged. *Follicles* (1) 2 on a separate plant without flowers, towards base of branches, upright, 13–14 cm long, 7–8 mm thick, longitudinally striped and mottled. Fig. 4.

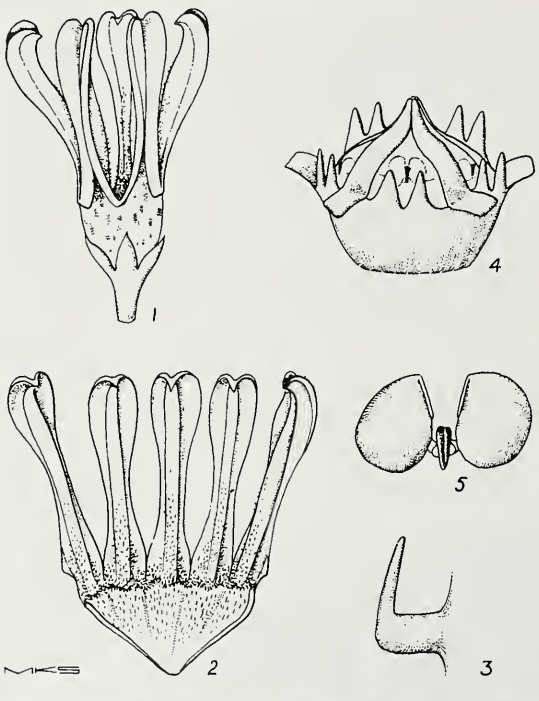


Fig. 4.—*Caralluma multiflora*. 1, open flower, ×3; 2, corolla opened out, ×3; 3, papilla with sharp tip turning at right-angles, ×100; 4, corona, ×15; 5, pollinia and carrier, ×60. (*Hanekom* 2335).

Cape.—3119 (Calvinia): Kareeboomfontein, west of Rebuniekop (–DA), rocky ground with some protection from shrublets, 24/8/74, *Hanekom 2335*; 17/10/75, *Hanekom 2475*.

This is a relatively robust succulent which, like so many members of the Stapelieae, is found on rocky slopes in the half-shade of shrublets. Under favourable conditions in the field it may be so floriferous that the flowers almost obscure the branches. Up to 12 flowers are produced in fascicles from each flowering eye, all developing together. It is presumed that under normal conditions of warmth and sunshine, all flowers would be open together, but this has not actually been observed. The first plants collected by Mr W. J. Hanekom flowered after a short period in cultivation at the Botanical Research Institute in Pretoria and were not considered to be entirely normal. In 1975 Mr Hanekom brought two specimens direct from the veld, one in the initial stages of flowering and the other with several follicles. A few flowers were open with the lobes erect-spreading, whereas those not open showed a tendency for the corolla-lobes to remain slightly cohering at the tips. The papillae-like hairs on the inside of the corolla have an unusual shape, being bent approximately at right angles about the middle and acuminate. The corolla is dark maroon to black.

In spite of enquiries among Cape collectors, no record of the species other than the present one seems to have been made. One wonders how it happens that such an interesting species should remain unheralded for so long.

The fruiting specimen brought by Mr Hanekom showed the follicles arising from flowering eyes towards the base of the branches, whereas the flowers on the other specimen were from younger flowering eyes towards the tips of the branches. This illustrates a feature of Stapelieae, where the fertilized ovary undergoes a protracted resting period, after which the follicles elongate fairly rapidly to maturity. The number of follicles is usually very small by comparison with the large number of flowers. This is a result of the highly specialized and frequently unsuccessful mechanism for insect pollination. But nature has introduced compensations by providing an abundance of seeds in each follicle: each seed is attached to a very light and delicate cluster of hairs, which act as parachutes for wide seed dispersal.

R. A. Dyer

TWO NEW SPECIES OF *BRACHYSTELMA*

Brachystelma canum *R. A. Dyer*, sp. nov., *B. macropetalo* (Schltr.) N.E. Br. affine, foliis oblongo-ellipticis breviter pubescentibus canis, floribus minoribus lobis intus glabris, corona breviter campanulata, lobis interioribus parvis pulvinatis differt.

Herba erecta, usque 30 cm alta, breviter pubescens, basi 1–2 ramosa, (? radicibus fasciculatis incrassatis), internodiis 2–4 cm longis. *Folia* elliptico-oblonga, 2–4 cm longa, 5–10 mm lata, sensim basin versus attenuata, molliter pubescentia cana, marginibus leviter undulatis, plus minusve plicatis. *Flores* (1) 2 extra axillares producti; pedicelli circiter 1 cm longi. *Sepala* lineari-lanceolata, circiter 4 mm longa. *Corolla* 9–11 mm longa, basi 1,5 mm connata; lobi lineari-lanceolati, extus pubescentes, intus glabri, leviter replicati. *Corona* 0,25 mm supra corollae basin expansa, campanulata, 1,75-2 mm diam., 5-saccata margine integro; coronae lobi interiores parvi pulvinati.

Type: Transvaal, 2625 (Delareyville): 25 km N.E. of Setlagoli, on road to Mafeking, sandy *Terminalia*-veld (–AB), rare, about 1300 m alt., 16th February 1956 *J. P. H. Acocks 18774* (PRE, holo.).

Herb erect, up to about 30 cm tall, with underground stem up to 6 cm long or more (roots not recorded but assumed to be succulent, fascicled, more or less cylindric or fusiform); branches 1–2 from the base, unbranched above, shortly and softly pubescent, basal internodes 2–4 cm long becoming gradually shorter as growth continues. *Leaves* elliptic-oblong, 2–4 cm long, 5–10 mm broad, gradually tapering to the base with no distinct petiole, finely pubescent, grey, margins slightly undulate inclined to fold upwards. *Flowers* usually 2 together, extra axillary, opening in succession. *Calyx* divided to base, with segments linear-lanceolate, about 4 mm long, pubescent. *Corolla* 9–11 mm long, lobed almost to the base (united for 1,5 mm); lobes linear-lanceolate, with

margins somewhat replicate, finely pubescent on outer surface, glabrous on inner surface. *Staminal column* 1,5 mm high. *Corona* appearing to arise ⅓ up staminal column 1,5 mm high, more or less campanulate, 1,75–2 mm broad, forming 5 pockets with outer margin entire; inner corona lobes represented by 5 swellings at base of filaments; filaments conspicuous, oblong with slight narrowing at the middle. *Pollinia* subpyriform, about 0,25 mm long with very short connectives to carrier. FIG. 5.

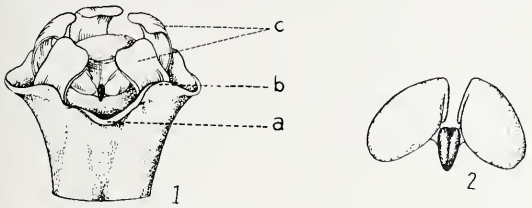


FIG. 5.—*Brachystelma canum*. 1, staminal column and corona, ×15; 1a, outer margin of outer corona-pocket; 1b, rudimentary inner corona lobs pressed on base of anther; 1c, anthers; 2, pollinia, with carrier, ×60. (*Acocks* 18774).

This is a further species known only from a single specimen collected by J. P. H. Acocks nearly twenty years ago. Because of the sandy nature of the soil the root system was comparatively deeply buried below ground level and the collector did not record whether it was a single tuber or a cluster of fleshy roots. The habit of growth and floral structure indicate a close relationship with *B. macropetalum* (Schltr.) N.E. Br., and for this reason it is suggested that the plant has a cluster of fleshy roots. This was one of the characters on which Schlechter in Bot. Jahrb. 20, Beibl. 51:50 (1895), established the genus *Brachystelmaria* as distinct from *Brachystelma* R. Br., but N.E. Brown in Fl. Cap. 1908 did not uphold Schlechter's segregations.

Brachystelma ngomense *R. A. Dyer*, sp. nov., herba tuberosa prostrata; corolla circiter 10 mm longa, infra medium connata tubulata; corona late campanulata, 4 mm diam. 2,5–3 mm alta, margine incurvata distinguitur.

Tuber subglobosa, 2–3 cm diam.; rami 1–3 annui prostrati, usque 10 mm (cult. 20 mm) longi, sparsim ramulosi, glabri vel minute pubescentes. *Folia* ovata vel lanceolata, usque circiter 1,5 cm longa (cult. 2 cm×1,5 cm), breviter petiolata, glabra. *Flores* 1–2 extra axillares producti; pedicelli 5–10 mm longi. *Sepala* lanceolata, 2–3 mm longa. *Corolla* circiter 10 mm longa, infra medium connata, late campanulata: tubus circiter 5 mm diam., intus albidus rubromaculatus; lobi ovato-triangulares, ± 5 mm longi, patentes, leviter replicati, atropurpurei, apice albido. *Corona exterior* campanulata, 4 mm diam., 2,5–3 mm alta, 5-marsupiiformis, margine incurvata, lobis interioribus confluens; lobi interiores breves. *Pollinia* ±0,25 longa, subpyriformes, caudiculis brevissimis.

TYPE: Natal, 2731 (Louwsburg), Ngotshe district, Ngome (–CD), near sawmill on rock-sheets, 7 December 1975, *Hilliard & Burtt 8441* (PRE, holo.; NU).

Tuber subglobose, 2,0–3,0 cm diam., with 1–3 annual stems. *Stems* slender, prostrate, glabrous or minutely pubescent, sparsely branched, about 10 cm long (up to 20 cm under cultivation). *Leaves* ovate to lanceolate, up to about 1,5 cm long (2 cm×1,5 cm under cult.) glabrous. *Flowers* 1–2, subaxillary; pedicels ±1 cm long, ascending. *Sepals* lanceolate, 2–3 mm long. Corolla with the tube slightly bulging in bud, 1 cm long, divided to about ½ way; tube campanulate, ±5 mm diam. with flattish base, slightly bulged inwards below the sinuses, making the mouth obtusely 5-angled; white within and purple mottled; lobes triangular-ovate, ±5 mm long, spreading-recurved, concave on upper side towards base, replicate towards apex, dark red or maroon, with the apex a small white mucro. *Corona* campanulate, 4 mm diam., 2,5–3,0 mm high, overtopping the staminal column, forming 5 deep pockets, with minutely toothed incurved outer margin, confluent with the short incurved inner corona-lobes; inner corona-lobes pressed to base of anthers. *Pollinia* ±0,25 mm long, subpyriform, with translucent upper-inner margin, attached by very short caudicles to carrier with minute lateral bulges. FIG. 6.

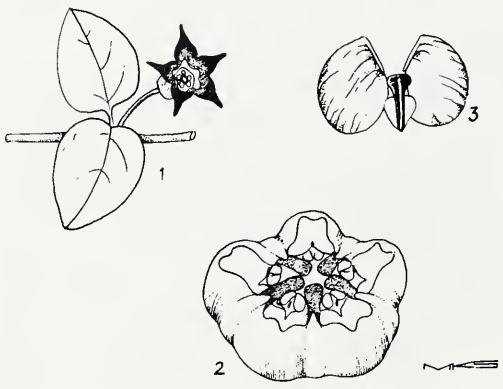


FIG. 6.—*Brachystelma ngomense*. 1, twig, natural size; 2, corona, ×7,5; 3, pollinia, with carrier, ×60. (*Hilliard & Burtt* 8441).

This species was discovered by Dr Olive Hilliard and Mr Bill Burtt on a collecting expedition in December 1975, when they were asked to make records of any form of *Brachystelma pulchellum* (Harv.) Schltr. which they might encounter. *B. ngomense* seems to have no close relationship to any known species. Several tubers were collected in Natal near Ngome in a small area on the edge of sheets of exposed rock, but no plants were seen in the open veld. The corolla-lobes were described as rich dark satiny-red, while inside the tube was white with crimson mottling; the corona was dull mustard, overlaid red. A tuber flowered at the Botanical Research Institute in February 1976, when it was figured for eventual publication in Flowering Plants of Africa.

R. A. DYER

CEROPEGIA MAFEKINGENSIS, A NEW COMBINATION

In Flora Capensis 4,1:854 (1908) N. E. Brown described the species *Brachystelma mafekingense*. He based it on a small branch preserved in formalin received from Dr S. Schonland at the Albany Museum, Grahamstown. Dr Schonland, later Professor of Botany, Rhodes University, had received a plant from Mr Graham Green at Mafeking in November 1906 and had divided it between the Albany Museum

collection and the Royal Botanic Gardens Kew. A scrap of material of less than 2 cm high has remained in a capsule for nearly 70 years in the Albany Museum with no record of its distribution other than near Mafeking in the north-western Cape on the border of Botswana.

My work on the genus *Brachystelma* has been disjointed, because it has been a sporadic time filler between many other projects. Nevertheless, from time to time in recent years I have been specially curious to know what relationship *B. mafekingense* has to other species, since from Brown's description it seemed to be an odd man out.

Without this problem in mind, however, the Dinter material of *Brachystelma* in the South African Museum Herbarium, was borrowed from the National Botanic Gardens, Kirstenbosch in 1969. Two dwarf specimens puzzled me particularly at the time, *Dinter* 2701 and an unnumbered one. *Dinter* 2701 from near Grootfontein in South-West Africa had first been named in manuscript by Dinter as *Ceropegia* sp. which he later changed to *Blepharanthera nigra*. The second specimen although manifestly the same species, bears the name *Blepharostelma avasmontanum* Dinter. This was from the Auasberge south of Windhoek. A note on the sheets indicated that P. G. Greenway had examined the specimens in 1924 and had not been able to name them nor was E. P. Phillips prepared to do so when he studied them 1940. Because of my own indecision in classifying them in 1969, no mention of them was made in my article, including Dinter's other specimens, in Bothalia 10,2:373 (1971).

Belatedly in 1974, I became aware of the publication of a species under the name *Ceropegia patriciae* W. Rauh and G. Buchloh in Kakteen und andere Sukkulenten (1964). This species was based on a solitary specimen collected near Hammanskraal some 40 kilometres north of Pretoria on a joint expedition by Dr Rauh and Dave and Patricia Hardy. In spite of the 1600 km odd gap in the distribution records, I had no hesitation in identifying *Dinter* 2701 and its companion as specifically equal to *Ceropegia patriciae*. The recorded distribution of *C. patriciae* from northern and central South-West Africa via the north-eastern Cape to the northern Transvaal is by no means unique. Species such as *Brachystelma dinteri* Schltr.have a very similar recorded distribution pattern.

In 1975 all the material of *Brachystelma* was borrowed from the Albany Museum, Grahamstown. It did not take long to establish that *B. mafekingense* N.E. Br. is conspecific with *Ceropegia patriciae* Rauh & Buchloh, with the former specific epithet taking priority. The question arose into which of the two genera the species should be classified. Both *Brachystelma* and *Ceropegia* embrace a wide range of corolla and corona forms and the relative lengths of the corolla-tube and -lobes are the main distinguishing features. The distinction between the genera is not always clear-cut such as in the present case but, in my opinion, the weight of evidence is in favour of *Ceropegia*, with *C. pygmaea* Schinz being the nearest, yet distant, known relative. This makes it necessary to validate the new combination *Ceropegia mafekingensis*, which is done below. Among the material of the genus *Brachystelma* borrowed in 1975 from the Bolus Herbarium were two specimens collected by Dr F. Z. van der Merwe, Nos 46 and 92. They were sent to the Bolus Herbarium in 1942 from a bushy plain near Zeerust only about 50 km from the type locality of *B. mafekingense*, which they were found to match very closely.

Ceropegia mafekingensis (*N.E. Br.*) *R. A. Dyer* comb. nov. Type: Cape, near Mafeking, *Green* sub GRA 1683 (K, holo.; GRA!).

Brachystelma mafekingense N.E. Br. in Fl. Cap. 4,1: 854 (1908).

Ceropegia patriciae Rauh & Buchloh in Kakteen und andere Sukkulenten 8:151 (1964). Type: Transvaal, near Hammanskraal, *Rauh* 12369 (HEID). *C.* sp. Dinter ms. (No. 2701).

Blepharanthera nigra Dinter ms. (No. 2701).

Blepharostelma avasmontanum Dinter ms. (specimen without number).

Tuber ±8 cm diam., more or less depressed, 0–7 cm below ground, producing one or more annual stems. *Stems* branching from near base and appearing tufted, 1,5–5 cm high, puberulous. *Leaves* tapering into a short petiole or rounded at the base, oblong-lanceolate, spreading, 7–30 mm long, up to 7 mm broad, with margins half folded upwards, ± undulate, puberulous below, glabrous above. *Flowers* in 10–20-flowered umbellate cymes, the last terminal; pedicels 3–8 mm long, puberulous. *Sepals* narrowly lanceolate, 2–4 mm long. *Corolla* 10–12 mm long, divided to more than ½ way; tube 4–6 mm long, 3–3,5 mm diam., obtusely 5-angled, slightly narrowed to the mouth, outside minutely puberulous or papillate on the upper part, maculate with dark purple, glabrous within, yellow and purple punctate; lobes 6–7 mm long, free at tips, connivent at first, becoming slightly spreading, obovate-oblong, ±2 mm broad, auriculate at base, inflexed, acute at apex, margins replicate, minutely puberulous outside, glabrous, verrucose, and blackish on inner surface. *Corona* campanulate at base; outer lobes forming 5 pockets with the outer margin extending into lobules behind the base of the inner corona-lobes; inner corona-lobes arising from within the base of the outer corona, linear, obtuse, 2 mm long, incumbent-erect, much overtopping the staminal column with obtuse connivent tips minutely papillate. *Pollinia* globose-pyriform, ±0,25 mm long, with translucent beaked upper margin, with short, delicate caudicles and small carrier.

CAPE.—2525 (Mafeking): near Mafeking, Nov. 1906, *Green sub GRA 1683* (GRA).

TRANSVAAL.—2526 (Zeerust): bushy plain near Zeerust, *Van der Merwe 46; 92* (BOL). 2528 (Pretoria): Hammanskraal, *Rauh 12369* (HEID).

S.W.A.—1918 (Grootfontein): near Grootfontein *Dinter 2701* (SAM); 2217 (Windhoek) Auasberge, *Dinter* s.n. (SAM).

Two statements in Brown's original description helped to confuse my concept of the species. Firstly, the statement that the flowers were in a terminal, 10–12-flowered umbel and secondly, that the stems were "richly branched from near the base 4–7 cm above the tuber (Schonland)". The flowers are falsely terminal and the 4–7 cm length refers to the depth of the tuber below ground level. The height of the stem above ground of the type was only 1,5–2 cm. Rauh and Buchloh state that the stem may be up to 5 cm long in *C patriciae*, but in the single specimen they cite the tuber was more or less at ground level.

In conclusion, for the historical record, Miss M. Gunn was able to supply the following information about Mr Graham Green, who collected the type material of *C. mafekingensis*. Mr Green was appointed as a clerk in the Cape Colonial Service in 1887. Most of his appointments were in the eastern Cape, including Grahamstown. He was promoted to the post of magistrate of Mafeking in 1903, whence in 1906 he despatched the type material to the Albany Museum in Grahamstown.

I wish to express my appreciation of the loan of the material, which made this investigation possible.

R. A. DYER

CYPERACEAE

CYPERACEAE NEW TO THE FLORA OF NATAL

Since the publication of Ross's Flora of Natal (1972) two species of Cyperaceae new to the province have been recorded:

Courtoisia cyperoides (Roxb.) Nees (*Vorster* 2702; 2703) was found in April 1975 in the Mkuze Game Reserve along the borders of pans, growing on wet mud.

Material of *Mariscus squarrosus* (L.) C.B. Cl. (*Vorster* 2700) was collected at the same time and place. Another specimen, *Arnold* 865, was collected about 20 km from Cathedral Peak on the road to Estcourt in March 1975. In naming these specimens I follow Hooper in Fl. W. Trop. Afr. ed. 2, 3:294 (1972), who reduced *M. aristatus* Rottb. to a synonym of *M. squarrosus*.

Both these species are widely distributed throughout the hot, dry areas of Africa and Asia. Although they occur mostly in areas of low rainfall, they never occur far from seasonal pans usually growing intermingled with each other on wet mud along the shores. Both species are known from Botswana, South West Africa and the drier parts of Transvaal, and *M. squarrosus* also from the high, dry parts of Lesotho.

P. Vorster

FABACEAE

SOME OBSERVATIONS ON *ELEPHANTORRHIZA BURKEI* AND *E. ELEPHANTINA*

In a revision of the genus *Elephantorrhiza* Benth., in Bothalia 11:252 (1974), it was stated that "*E. burkei* appears to have smaller seeds than *E. elephantina*, but more fruiting material is required to confirm this." In an attempt to glean further information on this matter, populations of these two species growing naturally in the Pretoria National Botanic Garden were kept under observation from spring 1974 until the end of winter 1975.

In *E. elephantina* the flowering racemes are usually confined to the lower part of the stem with the result that the pods are normally suspended just above the ground or else rest on the ground where they tend to be inconspicuous. In *E. burkei*, however, the flowering racemes are borne on the branched stems some distance from the ground and so the pods are conspicuous, especially when mature or approaching maturity.

Seeds of both species were collected, particularly those of *E. burkei* about which less was known and which were far more numerous. Considerable variation in the shape of the seeds was noted in *E. burkei*, seeds varying from elliptic to almost quadrate, the latter as a result of the seeds being tightly compacted and laterally compressed in the pods. The seed dimensions recorded for *E. burkei* were 9–15×8–12×5–7 mm and those for *E. elephantina* 17–26×13–18×6–13 mm. These measurements confirmed the suspected existence of a difference in seed size between the two species, the seeds of *E. burkei* apparently being consistently smaller than those of *E. elephantina*. As indicated in Bothalia *l.c.*, the pods of *E. burkei* tend to be longer and narrower than those of *E. elephantina*.

At maturity the valves of the pods in both species separate from the margins, the margins persisting as an almost continuous but empty frame in a manner reminiscent of most species of *Entada* (see illustration in Palmer & Pitman, Trees S. Afr. 2:827, 1973). This is particularly conspicuous in *E. burkei* where the valves roll back and together with the margins usually persist on the plant for many months. In *E. elephantina* the pods tend to disintegrate and disappear more rapidly.

A considerable amount of variation in the size of individual plants was noted in the population of *E. elephantina*. Scattered in amongst the population were several plants that were substantially larger than the surrounding plants, almost as though they had been the recipients of a heavy application of fertilizer. A cytogenetical study of this population may yield interesting results and would give an indication of whether or not polyploidy is involved.

J. H. Ross

FRULLANIACEAE (HEPATICAE)

TYPIFICATION OF *FRULLANIA SYLVESTRIS*

When Sim described *Frullania sylvestris* in Trans. Roy. Soc. S. Afr. 15:40 (1926), no specimens were cited. In the only subsequent work dealing with this species, Arnell, Hepaticae of S. Afr. 138 (1963), no type was designated or any specimens cited, although the distribution is cited as ".....Knysna. Natal, several localities."

In the main collection of Sim's specimens, which is housed at PRE, there is only one specimen of this species, *Sim* s.n. in PRE Cryptogamic Herbarium (Hepaticae) 1740, annotated as follows in Sim's own hand:

"*Frullania sylvestris* Sim
Giants Castle, Natal. 5000'
Sept 1903, T.R. Sim."

I conclude that Sim's description was probably based on this specimen, and consequently regard it as the holotype.

P. Vorster

POACEAE

ODONTELYTRUM: A NEW GENERIC RECORD FOR SOUTH AFRICA

During an aquatic weed survey in December, 1974, Mr F. de W. Brand, a member of the Transvaal Provincial Administration, collected an aquatic grass, *Odontelytrum abyssinicum* Hack., in the municipal dam at Belfast (c. 2 000 m) in the eastern Transvaal. This gathering, *Brand* 44, represents a new generic record for South Africa. It has subsequently been re-collected by the author at Belfast, *Du Toit* 1083.

The monotypic genus *Odontelytrum*, first described by Hackel, was based on a Schimper specimen, collected in Ethiopia (Abyssinia) in stagnant water between Paffat and Dewra Tabor (c. 2700 m). The nearest known locality outside Ethiopia is Oljoro Nyuki on the Ngorongoro crater floor (c. 1900 m), in a *Cyperus*-swamp in Tanzania. The grass seems to prefer a cool climate in stagnant or slow-flowing water. It is possible that this grass spread to South Africa via the eastern mountain ranges being dispersed by waterbirds. This view is strengthened by the observations of Mr Brand, who stated that waterbirds relish the seeds and young shoots.

Although superficially resembling *Oryza longistaminata*, the wild rice, and *Oryzidium barnardii*, *Odontelytrum* is closely allied to *Pennisetum*, a genus with which it cannot be confused. On close examination, the long "awn" of *Odontelytrum* proves to be an elongate bristle of the involucre surrounding the spikelet. In the case of *Oryza* and *Oryzidium*, the awn arises from the lemma.

The specimen from the eastern Transvaal was identified in time for the genus to be included in Volume 2 of The Genera of Southern African Flowering Plants by R. A. Dyer (1976). Readers are referred to this publication for a full description of the genus. To facilitate identification and to encourage further observations on its distribution, a brief diagnostic description is given here.

Odontelytrum abyssinicum Hack. in Oestr. Bot Zeitschr. 48: 86 (1898); Stapf in Hook.Ic.Pl.31.t. 3074 (1922). Type: Aethiopia, between Paffat and Dewra Tabor, *Schimper* 1121.

Aquatic perennials, with soft spongy culms, leaves light green or purplish, minutely scabrid. *Inflorescence* a stout raceme, sheathed at the base. *Spikelets* solitary, purple or straw-coloured, and enveloped by an involucre of partially fused bristles. *Spikelets* two-flowered, the lower male, the upper bisexual. At maturity spikelets fall entire with the involucre.

P. C. V. Du T oi

RANUNCULACEAE

THE CORRECT NAME FOR *ANEMONE CAPENSIS*

In his write-up of *Anemone capensis* in Flower. Pl. Afr. 40: t. 1569 (1969), Oliver attributed the binomial to Lamarck (1783), pointing out that Lamarck made no mention at all of *Atragene capensis* L. (1753) in his description of *Anemone capensis* in Encycl. 1: 164 (1783) and therefore Lamarck was the sole author of *Anemone capensis*. Oliver also stated that the combination *Anemone capensis* (L.) Harv. (1860) based on *Atragene capensis* L. (1753) was a later homonym of *Anemone capensis* Lam. and therefore illegitimate.

This is true, but unfortunately Oliver overlooked *Atragene tenuifolia* L.f. (1781), which is conspecific with *Anemone capensis* Lam. and antedates it by two years. I have not been able to trace the holotype of *Atragene tenuifolia*, but Thunberg specimen No. 12999 in Herb. Thunberg, Uppsala, which is probably an isotype, agrees with our concept of *Anemone capensis*. The correct name to use, therefore, is *Anemon tenuifolia* (L.f.) DC. (1824).

The relevant synomy is as follows—

Anemone tenuifolia (L.f.) DC., Prodr. 1: 18 (1824). Type: Cape, *Thunberg* (holotype not traced, but isotype probably specimen No. 12999 in Thunberg Herbarium, UPS; PRE, photo.!).

Atragene capensis L., Sp. Pl. 543 (1753). Type: Cape (LINN 711.3; PRE, photo). *A. tenuifolia* L. f., Suppl. 270 (1781), as above. *A. tenuis* Thunb., Fl. Jap. 239 (1784). Type: none cited.

Anemone capensis Lam., Encycl. 1:164 (1783); Oliver in Flower. Pl. Afr. 40:t.1569 (1969). Type: Cape (specimen in Herb. Jussieu, P). *A. arborea* Hort. in Steud. Nom. ed. 95 (1840), nomen nudum. *A capensis* (L.) Harv. in Fl. Cap. 1: 3 (1859–60), nom. illeg.; Adamson in Fl. Cap. Penins. 401 (1950). *A capensis* (L.) Harv. var. *tenuifolia* Harv., l.c.

Pulsatilla africana Spreng., Syst. 2: 664 (1825). Type: none cited. *P. tenuifolia* (L.f.) Spreng., l.c.

D. J. B. Killic

RUTACEAE

*ZANTHOXYLUM LEPRIEURII**, A NEW RECORD FOR SOUTHERN AFRICA

The first specimen of this *Zanthoxylum* from Southern Africa was collected by Drs Codd and Dyer (No. 4564) in the Sibasa district of the Transvaal near Punda Milia in the Kruger National Park in October 1948. However, in the absence of fertile material, this specimen, like each of those collected in the Kruger Park and in north-eastern Natal (Tongaland) during the next twenty years, remained unidentified. In December 1969 good flowering material of both male and female plants was collected (*Moll* 4887, 4889) near Makanes Drift in Tongaland and it is these specimens which finally enabled the plants to be identified. There is still no fertile material from the Transvaal, although there is a photograph in the National Herbarium, Pretoria, of a fruiting branchlet collected by Mrs E. Jenkins north-east of Sibasa in the northern Transvaal.

*The taxonomic position of the genera *Zanthoxylum* L. and *Fagara* L. has long been a source of controversy. Most early taxonomists, for example, Benth. & Hook.f., Gen. Pl. 1 : 297 (1862), regarded the two as congeneric, but later opinion favoured the argument advanced by Engler in Pflanzenfam. 3,4:95–102 (1896), which supported the retention of both genera. In recent years evidence has accumulated which supports the view that the genera are not distinct. Following Hartley, in J.Arn.Arb. 47:171–221 (1966), and Waterman, in Taxon 24:361–366 (1975), *Fagara* and *Zanthoxylum* are here regarded as congeneric, *Zanthoxylum* being the correct name for the combined genera.

The specimens are referable to *Z. leprieurii* Guill. & Perr., a species described from Senegal, but widespread in the forests of west tropical Africa to the Equatoria Province of the Sudan, Uganda, Tanzania, northern Mozambique, Zaire and Angola. Although not specifically distinct, the Southern African plants do nevertheless differ from typical *Z. leprieurii* in certain characters.

In typical *Z. leprieurii* the inflorescence is a very robust structure up to 30 cm long with the axis 2–3 mm in diameter basally, and the axis and its many lateral branches are sparingly to densely glandular-puberulous, particularly the lateral branches. It is not clear whether the inflorescence is carried erect or whether it is pendulous as none of the collector's notes refer to this feature. The inflorescence in the Tongaland plants (and presumably in the Transvaal) is smaller, seldom attaining a length of 20 cm and the axis is slender and ±1 mm in diameter basally. The inflorescence in these plants is pendulous and glabrous, and the lateral branches are fewer and more widely spaced so that the inflorescence forms a more open lax panicle. The flowers are more consistently aggregated into fascicles along the lateral branches, particularly in the male, and there are fewer flowers per lateral branch. This contrasts with the tropical material where the flowers are more often solitary.

The Southern African specimens also differ from material of typical *Z. leprieurii* in having consistently smaller leaves with fewer pairs of smaller leaflets, but there is no discontinuity in any of these characters between specimens from the two areas.

Typical *Z. leprieurii* is a forest species which grows to a height of 27 m, while the Southern African plants grow on sandy soils as shrubs or small trees and seldom attain a height of 8 m. Plants are known from only two localities in Tongaland, namely, False Bay Park and the Makanes Drift-Sihangwane area where they form one of the constituents of the sand-forest and grow in association with species such as *Albizia forbesii* Benth., *Newtonia hildebrandtii* (Vatke) Torre and *Cleistanthus schlechteri* (Pax) Hutch., to name but a few. Only six male plants have been found at False Bay Park, but in the Makanes Drift-Sihangwane area plants are locally quite common.

In Tongaland the specimens of *Z. leprieurii* are entirely leafless in winter. In spring the young leaves and inflorescences appear together, but while the leaves develop the young flower buds remain closed for several months before finally opening. The male inflorescences are relatively long and conspicuous and project beyond the leaves, while the female inflorescences are usually smaller and are sometimes partially hidden in amongst the leaves.

Zanthoxylum leprieurii *Guill. & Perr.*, Fl. Seneg. Tent. 141 (1831). Type: Senegal, *Leprieur* (P, holo.!).

Fagara leprieurii (Guill. & Perr.) Engl. in Pflanzenfam. 3,4:118 (1896). *F. angolensis* Engl. in Bot. Jahrb. 23:148 (1896). Type: Angola, without locality, *Welwitsch* 4575 (K, iso.!). *F. nitens* (Hiern) Engl., Pflanzenw. Afr. 3,1:749 (1915). *F.* sp., Ross, Fl. Natal 213 (1973); Palmer & Pitman, Trees S. Afr. 2:982–3 (1973).

Zanthoxylum nitens Hiern, Cat. Afr. Pl. Welw. 1:112 (1896). Type: Angola, Golungo Alto, road to Bango, *Welwitsch* 4558 (K, iso.!).

The following specimens from Southern Africa have been examined:—

TRANSVAAL.—2231 (Pafuri): Kruger National Park, 5 km N.E. of Punda Milia, *Codd & Dyer 4564;* Kruger National Park, Punda Milia, *Van der Schijff 2930; 3803.*

NATAL.—2632 (Bela Vista): 8 km W. of Muzi border post, *Moll 5654* (NH). 2732 (Ubombo): 3,2 km N.E. of Makanes Drift, *Moll 4887; 4889; Ross 2368;* near Jobe's Kraal, *Garland 442;* 10 km Pongolo bridge/Maputa, *Moll 4382;* Sihangwane, *Tinley 901* (E,NU); *Pooley 727* (E, NU); 2 km W. of Sihangwane Store, *Moll 4880;* False Bay Park, *Ward 3850; Ross 2229.*

J. H. Ross

SELAGINELLACEAE (LYCOPSIDA)

SELAGINELLA IMBRICATA IN THE FLORA OF SOUTHERN AFRICA AREA

During August 1956 a specimen of *Selaginella imbricata* (*Story* 5841) was collected in the Kapupa Valley (12°34′ E, 17°21′ S) in the northwest of South West Africa. This species was not included in Prodr. Fl. S.W. Afr. The presence of *S. imbricata* in South West Africa is rather unexpected, as this species usually occurs in rather moist forest situations. The specimen was reported as occurring "along fissures in rocks in mountain gorge". Judging from the geographical situation, the area where the specimen was collected, must be extremely dry.

The find is of interest, firstly because it adds another species to the flora of South West Africa, and secondly, because it extends the known range of the species westwards by 1300 km. The nearest point from which it was previously known, is the Victoria Falls.

This is the first time the genus has been recorded from South West Africa, although a number of species occur in adjacent territories.

Two other specimens in the National Herbarium, also proved to be *S. imbricata* (Forsk.) Spring ex Decne. Apparently these two specimens, *Galpin* s.n. in PRE Cryptogamic Herbarium (Pteridophyta) 3532 from Devil's Hoek in the Royal National Park in 1928, and *Esterhuysen* 10823 from the "Turret" and "Amphlet" in the Cathkin Peak area in 1956, represent the only two collections from which this species is known in South Africa. This is about 1500 km south of the nearest known locality near Melsetter in Rhodesia.

Selaginella imbricata is widespread throughout the eastern part of Africa, from the escarpment between Mozambique and Rhodesia in the south to Arabia in the north. It occurs westwards along the Zambesi valley to at least as far as the Victoria Falls and, as already mentioned, is found in the extreme north-western part of South West Africa.

It would seem that the plant must be very rare in South Africa to have escaped more frequent collection, as it is quite a distinct and conspicuous species. It can easily be distinguished from other South African species because of the rhomboid outline of the branched stem system, which stands erect, as it is rather stiff, and is arranged in one plane like a fern frond, instead of being procumbent and closely adpressed to the substrate. It occurs in moist, shady forest situations against earth banks. Under dry conditions the plant rolls up into a series of ball- or clockspring-like structures, but unrolls again after rains.

While some species of *Selaginella* occur under moist conditions and cannot withstand drought, many species are xerophytes of the "resurrection" type. Such species are dry and inactive and more or less rolled up during the greater part of the year. As soon as they are moistened, however, the leafy branches unfold and the tiny leaves attain a green colour once again. *S. imbricata* is intermediate in this respect. Its habitat is generally not dry at all, but it is capable of surviving dry spells by going into quiescence.

P. Vorster

THELYPTERIDACEAE

NEW COMBINATIONS IN *THELYPTERIS*

Holttum in J. S. Afr. Bot. 40: 123—168 (1974) stated that the estimated 1 000 species in the family Thelypteridaceae can either be regarded as belonging to a single genus, *Thelypteris*, or they can be placed in a number of different genera. In Blumea 19: 17–52 (1971) he adopted the latter course by grouping the 450–500 Asian-Malesian species into various genera. "For comparative purposes", Holttum (1974) also classified the 55 African species of the family Thelypteridaceae according to this scheme. He added, however, that ". . . .for persons who are concerned only with Africa, or a part of Africa, it is reasonable to adopt one genus *Thelypteris*, as Prof. Schelpe has done in his account of the ferns in *Flora Zambesiaca* (1970)".

I agree with this approach, with the possible exception of *Ampelopteris*, a monotypic genus, which can easily be recognized by the unicellular forked hairs and numerous gemmae on the fronds.

The characters used to differentiate between the genera of Thelypteridaceae (pinna veins anastomosing or not, reduction of lower pinnae, hairiness or scaliness of fronds) are, in my opinion, not sufficient in the African context to justify division into genera. The presence or absence of indusia may be useful for subgeneric division, but will have to be studied in conjunction with other characters.

Holttum (1974) pointed out that some of the African taxa described in that paper still lack names in *Thelypteris*. For two of the South African species these combinations are made below, as they have not been proposed by Schelpe (in press):

Thelypteris altissima (*Holtt.*) *Vorster* comb. nov.
Christella altissima Holtt. in J. S. Afr. Bot. 40: 141 (1974).

Thelypteris prolifera (*Retz.*) *Vorster* comb. nov.
Hemionitis prolifera Retz., Obs. Bot. 6:38 (1791).
Ampelopteris prolifera (Retz.) Copel., Gen. Fil. 144 (1947).

P. Vorster

Bothalia 12, 2: 261–265 (1977)

World climate patterns in grassland and savanna and their relation to growing seasons

R. KIRK STEINHORST* and J. W. MORRIS†

ABSTRACT

The climate at eleven IBP savanna or grassland study sites from five continents are described and principal components analysis is used to compare them. A multivariate linear discriminant function based on mean monthly precipitation, mean monthly temperature, latitude and altitude, is used to predict the length of the growing season at each site. At most sites, the actual and predicted start and end of the growing season agreed closely. It is concluded that growing season on a world-wide basis may be predicted fairly reliably from a small number of abiotic variables by means of a multivariate discriminant function.

RESUME

CYCLES CLIMATOLOGIQUES MONDIAUX EN PRAIRIE ET SAVANE ET LEUR RELATION AVEC LES SAISONS DE CROISSANCE

Les climats en onze points d'étude de la savane ou de la prairie, choisis par le Programme Biologique International sur les cinq continents, sont décrits et comparés par le moyen de l'analyse des principaux composants. Une fonction discriminante linéaire multivariée, basée sur les moyennes mensuelles de la précipitation et de la température, sur la latitude et l'altitude, est utilisée pour prédire la longueur de la saison de croissance en chaque endroit. Dans la plupart des cas, il y a un excellent accord entre le calcul et l'observation pour le début et la fin de la saison de croissance. On en conclut que cette saison peut, à l'échelle mondiale, faire l'objet d'une prévision assez sûre à partir d'un petit nombre de données abiotiques et en utilisant une fonction discriminante multivariée.

INTRODUCTION

In this article we consider a variety of savanna and grassland sites and one tundra site, characterize their climates and relate climate to the conditions for growth of the natural vegetation of the sites. By so doing, we hope to better understand the factors involved in growing season determination. By growing season, we mean that period of the year from the time when environmental factors cease to limit growth, usually in spring, until they limit it again, usually in autumn.

With the present world population and limited food supplies it is important that we use all available land in an efficient manner for either agriculture, grazing, wood production, or conservation. As recently pointed out by Newman & Pickett (1974), the one uncontrollable factor which limits land productivity is weather. Success or failure of crops and of forage production are dramatically affected by whims of weather. Newman & Pickett suggest that knowledge of world climate will enable us to predict productive uses for each area. To apply this strategy, however, knowledge of how crops and other vegetation respond to climatic factors is required. For crops, and monospecific communities in general, physiological studies give us the required information concerning responses to light, temperature, precipitation, and other factors. For savanna, grassland, or tundra communities of many species, physiological studies give us no single answer. Another solution is required if we are to utilize such communities efficiently on a world-wide basis for grazing or fodder production.

The International Biological Program (IBP) gives us a unique opportunity to study these communities of many species. In this paper we include data from IBP grassland sites and one tundra site (eutrophic mire) falling in a range from 6° to 60° latitude, north and south of the equator from five continents (Table 1). Each site represents typical savanna, grassland or tundra vegetation under grazing, haying, or fallow conditions. The data include short-term specific weather records on at least a monthly basis and the associated growing seasons as determined subjectively by the investigators at each site. In order to predict conditions for growth of the local vegetation, we consider monthly precipitation and average temperature along with latitude and altitude.

* Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado, U.S.A. (Now at: Institute of Statistics, Texas A & M University, College Station, Texas).

† Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria, 0001.

TABLE 1.—Study sites and sources of data

Site	Latitude	Period of data measurement (month and year)	Contributor	Source
Australia, Armidale	30,5° S	10/69—9/70	K. J. Hutchinson & A. R. Till	Personal Communication
Czechoslovakia, Lanzhot	49° N	1/69—12/69	M. Rychnovská	Smíd (1972)
India, Kurukshetra	30° N	1/70—12/71	J. S. Singh	Singh & Yadava (1974)
India, Rajkot	22° N	1/71—12/71	S. C. Pandeya	Pandeya, *et al.* (1972)
Ireland, Glenamoy	54° N	1/70—12/71	J. J. Moore	Personal Communication
Ivory Coast, Lamto	6° N	1/69—12/70	M. Lamotte	Lamotte (1967), César & Menaut (1974), Lecordier (1974)
Netherlands, Terschelling	53° N	1/67—12/70	P. Ketner	Ketner (1972)
Norway, Hardangervidda	60° N	7/69—9/71	F. E. Wielgolaski	Skartveit, *et al.* (1975)
South Africa, Welgevonden	24° S	1/70—12/70	J. J. P. van Wyk	Personal Communication
United Kingdom, Moor House	54° N	1/68—12/68 and 1/71—12/71	O. W. Heal	Personal Communication
United States, Pawnee	41° N	1/69—12/71	U.S./IBP Grassland Biome	Biome data bank

CHARACTERIZATION OF CLIMATE TYPES BY PRINCIPAL COMPONENTS ANALYSIS

There is a wide range of climates, both tropical and temperate, represented in the sites included in the study. Of the tropical climate sites, Lamto, Ivory Coast, has uniform temperatures with heavy precipitation from March to October with a brief respite in mid-summer. The two Indian sites have three seasons; a rainy season from mid-June to September, a cool dry season from October to February, and a hot dry season from March to mid-June. Welgevonden, South Africa, is a dry sub-tropical savanna site with summer rainfall. The temperate sites range from 30 to 60° from the equator. They have seasons dictated by the angle of the sun's incoming rays. Armidale, Australia, is a cool temperate rangeland with moderate precipitation, which is fairly uniform but heaviest in summer. Temperate sites which are relatively humid are Lanzhot, Czechoslovakia; Glenamoy, Ireland; Terschelling, Netherlands; Hardangervidda, Norway; and Moor House, U.K. The season of rainfall varies greatly among temperate sites. For example, Ireland's heavy precipitation occurs in November, December and January, whereas Terschelling has uniform rainfall throughout the year. The Pawnee Site in the United States is very dry relative to the other sites.

A number of these sites have climates which are influenced by geographical features. The Netherlands, Norway, Ireland, Ivory Coast and United Kingdom sites are influenced by proximity to the ocean. Both the Czechoslovakian and the United States sites are continental. The Pawnee (U.S.) site's weather is furthermore modified by the north-south Rocky Mountain Range, a few kilometres to the west. Czechoslovakia on the other hand is bounded by the major east-west mountain ranges of Europe. Another site affected by mountains is the northern India site (Kurukshetra), whose climate is influenced to some extent by the Himalayas.

All in all, these sites have a fairly predictable pattern of monthly temperature based on incoming radiation, but they present a mosaic of precipitation regimes. Principal component analysis (PCA) (Seal, 1964) was used to illustrate this contrast. For temperature, using the twelve monthly values as attributes over the eleven sites (entities), the first component (an average temperature component) accounts for 94% of total variability in the data and the second component brings the cumulative per cent to 99%. The second component contrasts summer and winter temperatures, yielding a range from very uniform monthly temperatures (Ivory Coast, Ireland and U.K.) to strongly seasonal ones, including U.S.A. and Czechoslovakia (Fig. 1). The first component separates warm sites, such as the Indian and the Ivory Coast sites, from cold ones such as U.K. and Norway. As a hierarchical cluster analysis (Johnson, 1967) on temperature correlation or seasonal patterns grouped the sites in the same manner as component two of the PCA, except for the U.S. site which, for these data, showed a monthly temperature pattern similar to the Moor House site, these results are not presented. A hierarchical cluster analysis using euclidian distance, that is, temperature magnitudes rather than patterns, yielded clusters predictably similar to the first component of the PCA and is also not presented.

For mean monthly precipitation values over the eleven sites, the first three principal components account for only 52%, then 75%, then 86% of the total variability. There is no discernable pattern of rainfall along latitudinal or altitudinal gradients. This result follows from the above characterization of climate types since the precipitation at these sites is variously affected by oceans, mountains, and other non-regular causes. In contrast to the sun's orbit, which is the principal regulator of temperature, there is no single unifying phenomenon that controls precipitation.

DETERMINATION OF GROWING SEASON BY DISCRIMINANT ANALYSIS

If one were to take a plant physiological approach to the specification of conditions for growth, one would consider available solar radiation, maximum and minimum air temperature, soil temperature, number of daylight hours (related to latitude), available moisture and phenological stage. We have taken four variables as integrators of all these factors, namely: mean monthly temperature, monthly precipitation, latitude and altitude. The growing seasons for the 11 sites do not simply commence and end as the sun progresses to and from the equator. If this were so, either average monthly temperature or latitude would suffice to predict growing seasons.

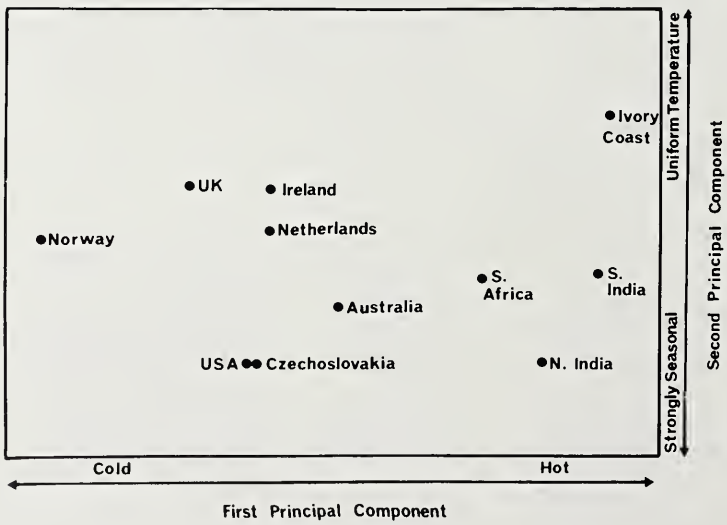


FIG. 1.—First and second principal components of monthly mean temperature data for the eleven sites.

A step-wise discriminant algorithm (Dixon, 1971) was applied to determine if some combination of these four variables was a good indicator of growth. Each month, at each site, was classified as either a growing- or non-growing-season month according to the dates defining the length of the growing season supplied by each investigator. The means for the four response variables are given in Table 2, and the pooled covariance matrix is given in Table 3.

TABLE 2.—Mean values (F) over the eleven sites for the four responses

Variable	Growing season months	Non-growing season months	All months
Precipitation (mm)....	89,96	43,98	68,36
Temperature (°C)....	16,55	9,99	13,67
Latitude (degrees N or S).....	38,86	38,09	38,50
Altitude (m).....	483,61	569,02	523,73

TABLE 3.—Pooled covariance matrix($\hat{\Sigma}$) of variances and covariances among the four responses

	Precipitation	Temperature	Latitude	Altitude
Precipitation.	4227,66	—	—	—
Temperature.	−47,66	110,05	—	—
Latitude.....	114,23	−139,94	271,65	—
Altitude.....	−6254,53	−1872,56	1284,00	254708,75

Data from South Africa and Australia were displaced by six months for the calculations so that "summer" and "winter" seasons would coincide with northern hemisphere seasons. Growing season months clearly have more rainfall and are warmer (Table 2). The latitude and altitude means differ in the two groups only in so far as the sites at different latitudes or altitudes have greater than or less than 6 months of growth. Curiously, there are relatively more growing season months at greater latitudes than non-growing months at those latitudes (group means of 38,9 and 38,1 respectively), although the difference is not significant.

The most important single variable is precipitation (t-test between growing and non-growing groups yield a significance of $p<0,0005$). However, when used as an indicator of growth, this variable by itself incorrectly labels 35 growing season months as non-growing months while correctly categorizing 84 months. The remaining 13 months were non-growing months mis-specified as growing months. The best discriminant function uses either all four variables, in which 29 of 132 months are mis-specified, or all variables excluding altitude for which 29 of, 132 months are also mis-specified. Latitude is needed in addition to precipitation and temperature in order to predict growth more accurately for some cool sites. Using all four variables, the multivariate t-test for groups yields a significance of $p<0,0005$. While it is clear that the largest difference between the growing and the non-growing months is their precipitation, precipitation alone is not sufficient to predict suitable conditions for growth.

Using all four variables the discriminant function for group i is

$$-\tfrac{1}{2}\hat{\mu}^1{}_i\ \hat{\Sigma}^{-1}\hat{\mu}_i+\hat{\mu}^1{}_i\ \hat{\Sigma}^{-1}x=a_i+b^1{}_i x$$

where μ_i is the four-variate mean for group i in Table 2, $\hat{\Sigma}$ is the pooled estimate of the variance-covariance matrix (Table 3), and x is the four variate response for a particular site and month. For the growing season group, $a_1=-27,6731$ and $b^1{}_1=(0,02709,\ 1,20478,\ 0,71537,\ 0,00781)$; for the non-growing season months one obtains $a_2=-19,60077$ and $b^1{}_2=(0,01511,\ 0,99297,\ 0,61318,\ 0,00681)$. After cancelling constant terms the posterior probability of being in group i is:

$$\frac{\pi_i e^{a_1+b^1{}_i x}}{\pi_1 e^{a_1+b^1{}_1 x}+\pi_2 e^{a_2+b^1{}_2 x}}$$

where π_1 and π_2 are the prior probabilities of being in the growing and non-growing groups, respectively (Dixon, 1971). Both π_1 and π_2 are taken to be one-half in this case. Prior probabilities are those based on the assumption or hypothesis under investigation, in this instance, that a month has an equal chance of being either a growing or a non-growing month. The two posterior probabilities, in this instance, are the chances of a month being a growing and non-growing month, calculated by substitution in the above equation of the month's precipitation, temperature, latitude and altitude values using (a_1, $b^1{}_1$) and (a_2, $b^1{}_2$), respectively. Posterior probabilities were calculated for each month at each site and each month as classified as growing or non-growing, depending on which posterior probability was greatest.

In Fig. 2 the growing seasons as given by the investigators are compared with the calculated growing seasons from the four-variable discriminant analysis. There are a total of 103 of 132 months correctly specified, whereas 17 growing season months were incorrectly classified as non-growing months and 12 non-growing season months were specified as suitable for growth. Half of the misclassified months were for tropical countries where growth would appear to be regulated by something in addition to rainfall and temperature. Predictions for both Indian sites and the Ivory Coast were particularly poor while those for South Africa and Australia are acceptable. On the other hand, the growing season was precisely predicted at Hardangervidda. Other temperate locations were treated relatively well, except that the linear discriminant technique was not able to accurately predict initiation of growth at Glenamoy, Ireland.

DISCUSSION AND CONCLUSIONS

Although the 11 sites represent vastly differing climates, including various combinations of temperature and moisture regimes, use of multivariate linear discriminant analysis suggests that, over a large portion of the globe, growing season is basically a function of precipitation and temperature with some modification due to latitude. Given these three variables, altitude may be of slight additional significance. Growth in tropical areas is dependent upon other or additional factors, including possibly mean monthly minimum temperature. The unsatisfactory predictions could also be accounted for by the use of one or two years' records instead of long-term averages in the calculations. The success in correctly classifying conditions conducive to growth using a multivariate linear function of three or four variables suggests that a plant community approach, as opposed to species-specific physiological approaches, can be successful.

It is possible to predict conditions suitable for growth at the community level on a global basis using a few abiotic variables. Future research can be directed at finding particular response curve relationships between initiation and termination of growth and

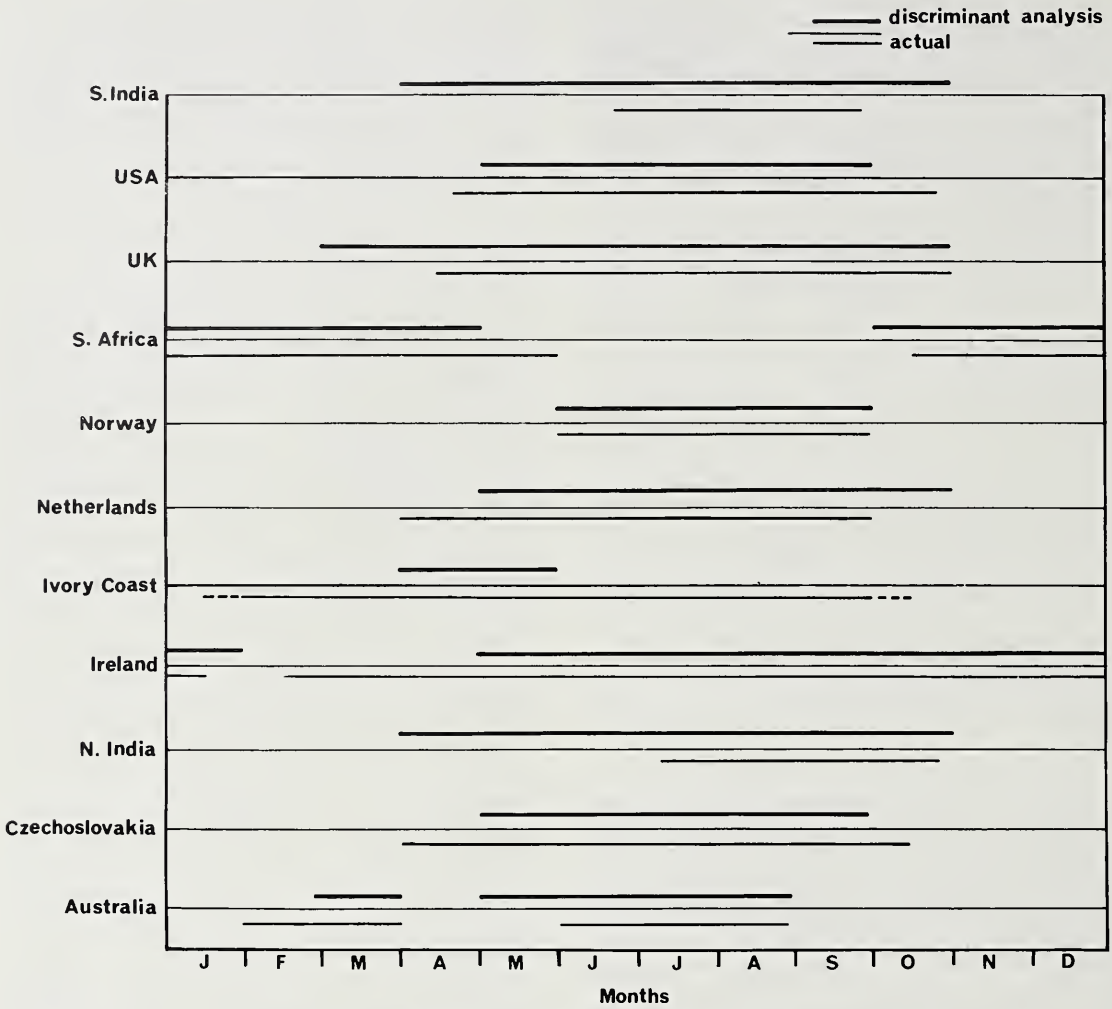


FIG. 2—Comparison of actual and predicted length of growing season at each site.

these factors. Until such research is done, the discriminant function used here gives us a reasonable tool for determining growing season. Management strategists can use this function to predict the possible outcomes of various strategies under conditions which have not occurred previously. For example, if one anticipates a cool wet spring, representative precipitation and temperature figures can be supplied and the effect on the start and end of the growing season may be predicted.

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UITTREKSEL

Elf IBP savanne- en grasveldstudiegebiede (vanaf vyf vastelande) se klimaat word beskryf en met behulp van hoofkomponentanalise vergelyk. 'n Veelvoudige lineêre diskriminantfunksie word gebruik om die lengte van die groei-seisoen vir elke gebied te bereken. Die gemiddelde maandelikse reënval, gemiddelde maandelikse temperatuur, lengtegraad en hoogte bo seespieël word gebruik om hierdie funksie te bereken. Vir die meeste van die gebiede was daar min verskil tussen die werklike en die berekende aanvang en einde van die groeiseisoen. Daar word tot die gevolgtrekking gekom dat die groeiseisoen redelik betroubaar, wêreldwyd bereken kan word met behulp van 'n veelvoudige diskriminantfunksie en 'n klein aantal abiotiese gegewens.

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Automatic classification of the highveld grassland of Lichtenburg, south-western Transvaal*

J. W. MORRIS†

ABSTRACT

A quantative, semi-detailed plant ecological study of the area between 25° 54′ and 26° 22′ E and 26° 00′ and 26° 20′ S, situated around the town of Lichtenburg in the south-western Transvaal, South Africa, is reported. Mean annual temperature of the study area is 17 °C and annual rainfall is about 600 mm. A basic difference is recognised between the Bankenveld Land System and the CT Grassland Land System. The former is underlain by dolomite with lithosolic soils, Bankenveld vegetation and cattle ranching as the chief land-use, whereas the latter is underlain by granite, Ventersdorp lavas, Dwyka tillite and surface limestone with Shorrocks, Mangano and Lichtenburg series soils, *Cymbopogon-Themeda* Veld vegetation and extensive cultivation of maize as the chief land-use. One hundred and ten 16 m^2 quadrats were placed within each Land System by means of a stratified-random strategy. Of the 247 species encountered, nearly 100 occurred in less than six quadrats. *Themeda triandra, Aristida congesta, Elionurus argenteus, Anthospermum rigidum* and *Justicia anagaloides* were common throughout. Two association analyses were carried out and 15 final groups were interpreted out of a total of 21 groups.

RESUME

CLASSIFICATION QUANTITATIVE DE LA PRAIRIE DE HAUTES TERRES DE LICHTENBURG, SUD-OUEST DU TRANSVAAL

On expose les résultats d'une étude phyto-écologique quantitative et semi-détaillée de la région comprise entre 25° 54′ *et* 26° 22′ *E. et* 26° 00 *et* 26° 20′ *S., autour de la ville de Lichtenburg dans le sud-ouest du Transvaal, Afrique du Sud. La moyenne annuelle de la température y est de* 17 °C *et la hauteur de pluie d'environ* 600 *mm. On reconnait une différence fondamentale entre le Bankenveld Land System et le CT Grassland Land System. Le premier est supporté par de la dolomite avec des lithosols, une végétation du type Bankenveld et l'élevage du bétail constituant la principale utilisation du terrain; tandis qu'au second sont sousjacents du granite, des laves de Ventersdorp, de la tillite de Dwyka et des calcaires de surface avec des sols des séries de Shorrocks, Mangano et Lichtenburg sur lesquels pousse une végétation de prairie à* Cymbopogon—Themeda *et dont la principale utilisation est la culture extensive du maïs. Cent et dix carrés de* 16 *m de côté ont été répartis sur chaque système selon la technique de stratification aléatoire. Des* 247 *espèces rencontrées, près de* 100 *ont été trouvées sur moins de six carrés.* Themeda triandra, Aristida congesta, Elionurus argenteus, Anthospermum rigidum *et* Justicia anagaloides *étaient communes partout. Deux analyses d'association ont été exécutées et d'un total de* 21 *groupes,* 15 *groupes finals ont été interprétés.*

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INTRODUCTION

The overall model for the ecological survey of the natural and semi-natural vegetation of the Highveld Agricultural Region of South Africa was designed by D. Edwards and J. C. Scheepers of the Botanical Research Institute. At an early stage, they decided that instead of spreading surveying efforts equally over the whole Region of approximately 11 655 000 ha, the Key Area approach, whereby efforts would initially be concentrated in the Lichtenburg, Maquassie, Kroonstad, Bethlehem and Villiers Key Areas, would be used. Each Key Area is a quarter degree square in extent and covers approximately 69 000 ha. Individual surveys of these five areas would be followed by extrapolatory surveys linking the areas. The aim of the survey reported here, a contribution towards the Highveld Region survey, was an account of the plant ecology of the Lichtenburg Key Area. A report on the Kroonstad and Bethlehem Areas (Scheepers, 1975) has already been produced.

The basic sampling strategy of 4 by 4 m quadrats, with a stratified-random distribution, was chosen during preliminary studies for the Kroonstad Area and the Lichtenburg and Bethlehem surveys followed suit to aid later comparison and extrapolation. The technique of association analysis was chosen to synthesize the results of each survey.

Two Land Systems (Dowling, 1968; Mabbutt, 1968) occur in the Lichtenburg Key Area. In this communication they are referred to, for convenience and brevity, as CT Grassland and Bankenveld Land Systems. The former includes Dry *Cymbopogon-Themeda* Veld and Sandy *Cymbopogon-Themeda* Veld and the latter covers part of Bankenveld (Acocks, 1953). The main features of and differences between the two Land Systems are detailed later. Briefly, Bankenveld lies on an area of dolomitic lithosol

* Forms part of a Ph.D thesis submitted to the University of Natal (Morris, 1973).

† Botanical Research Institute, Department of Agricultural Technical Services, Private Bag X101, Pretoria.

north of Lichtenburg where a great deal of the natural and semi-natural vegetation (physiognomically a grassland) remains and the main land-use activity is cattle and sheep farming. CT Grassland is an extensively-cultivated area south, east and west of Lichtenburg where maize is the chief crop. Natural and semi-natural vegetation is rare but, where still encountered, the physiognomic structure is grassland or savanna. In general, it is only small rock outcrops and poorly-drained areas which are not ploughed in the CT Grassland Land System.

1. DESCRIPTION OF STUDY AREA

1.1 *Location*

The location of the study area and its position relative to towns in the South-western Transvaal, South Africa are indicated in Fig. 1. Lichtenburg is the only town situated in the area. Initially, the area for study was the 2626AA quarter degree square but as parts were extensively cultivated the area was enlarged, as illustrated in Fig. 1, to enable placement of enough sampling points in relatively undisturbed vegetation. A rectangular shape was retained even though much of the enlarged area was not sampled. The quarter degree square covers about 69 000 ha and the whole study area about 177 000 ha.

1.2 *Climate*

Apart from precipitation and air temperature records, no climatic data are available from within the study area. Data from Potchefstroom, and even Pretoria, are used to complete the description of climate given below. Where data from outside the study area are used, they are intended as indications of conditions prevailing within the area and no more.

1.2.1 *Radiation and sunshine*

Few meteorological stations in South Africa record radiation. The station nearest to Lichtenburg is at Pretoria, half a degree further north and 200 km east. The instrument at Pretoria is a Kipp solarimeter and all measurements are from a horizontal surface. The percentage radiation received at the top of the atmosphere, but not reaching the surface of the earth at Pretoria, averages 39 percent annually with a maximum attenuation of 45 percent in December and minimum of 31 percent in June (Schulze, 1965).

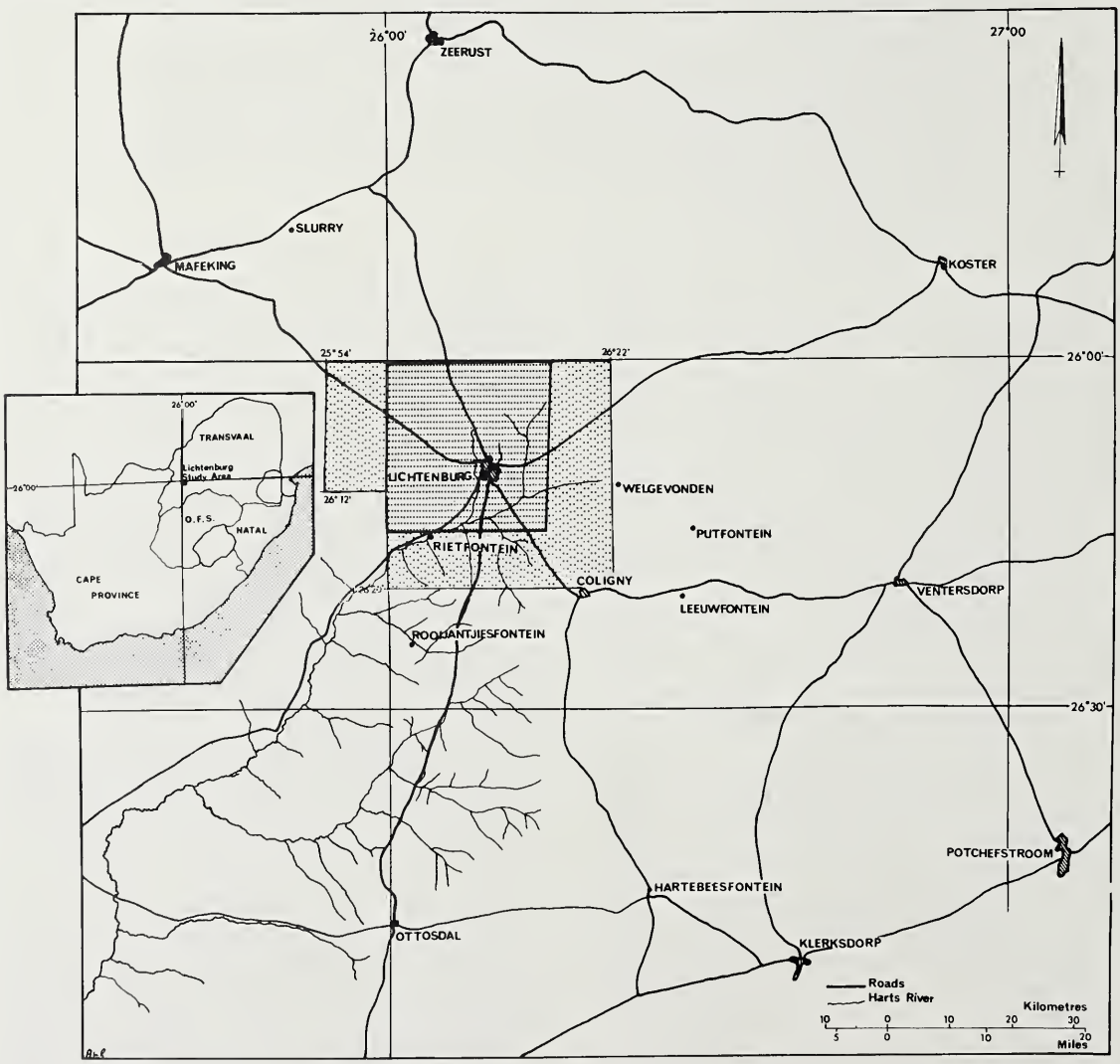


FIG. 1.—Locality of study area. Dark shading indicates 2626AA quarter degree square and lighter shading the enlarged study area. Inset: position in South Africa.

The monthly march of radiation at Pretoria is given by Weather Bureau (1968). The highest mean daily sums occur in summer from October to February when the global radiation exceeds 530 cal/cm²/day and the lowest mean daily sums in June and July (less than 360 cal/cm²/day). Radiation increases sharply from July to September and then stays fairly constant during summer before starting to decrease in February. The levelling off of radiation in summer is due to an increase in cloudiness compensating for radiation increases during this season. Diffuse radiation varies from over 150 cal/cm²/day in summer to less than 80 cal/cm²/day in winter. The highest sum of radiation recorded on a single day (800 cal/cm²) occurred during the month of January and the lowest (27 cal/cm²) during July (Schulze, 1965).

1.2.2 *Air temperature*

Although air temperature data have been recorded at Lichtenburg since 1905, observations until 1950 are the most recently published statistics (Weather Bureau, 1954). During that period the mean of daily maximum temperature varied from over 28 °C in December and January to under 20 °C in June and July. Mean of daily minimum was about 15 °C in January and February and less than 2 °C in June and July. Of more interest ecologically are the extreme maxima and minima (Walter & Leith, 1960). Extreme maximum temperatures in summer (September to February) exceed 35 °C while in winter the maximum recorded temperatures exceed 25 °C (July). Extreme minima below –5°C occur from May to August. In mid-summer (December to February) the extreme minimum temperature is above 3 °C.

1.2.3 *Grass minimum temperature and frost*

Mean grass minimum temperature at Potchefstroom (Schulze, 1965) varies from 11 °C in December, January and February to below –5 °C in June and July. The maximum exceeds 16 °C from November to March and drops to 8 °C in July while the minimum temperatures throughout the year (except February) are below 1 °C. The extreme minimum of –17 °C was recorded during July.

In the absence of observations on frost occurrence, climatologists have used various air temperatures to indicate the occurrence of frost. If the criteria of the publication Weather Bureau (1954), namely a minimum temperature less than 0 °C in a Stevenson screen 1,2 m above the surface, are accepted, Lichtenburg averages 106 days per annum (30-year records) with a possibility of experiencing frost. The average first date is 19th May and the average last date is 2nd September. As the average number of days on which frost actually occurs is 26, frost may be expected one night in four from the middle of May until the end of August. The extreme first date was 16th April and the extreme last date on which frost has been recorded was 26th September.

1.2.4 *Soil temperature*

Soil temperatures have been recorded at Potchefstroom for five years (Schulze, 1965). The highest monthly mean temperatures have been recorded at 1400 hours in November, December, January and February when the temperature exceeded 29 °C at 10 cm and 24 °C at 20 cm. The lowest temperatures (0800 hours) in June and July at these depths, where most plant roots are located, were 8,3 °C at 10 cm and 10,2 °C at 20 cm.

1.2.5 *Surface wind*

No information on surface wind is available from within the study area but the general features may be determined from a knowledge of air circulation patterns over South Africa and from observations of wind speed and direction at nearby meteorological stations. In general, there seems to be little seasonal change in wind direction or force. Winds with a northerly component predominate, but it is difficult to assign any one prevailing direction according to Schulze (1965). The northerly component results from the normal anticyclonic circulation of air around a high pressure cell located over the interior of South Africa throughout the year.

TABLE 1.—Mean monthly rainfall in mm (r) and mean number of days with rain (d) at the seven stations with recording periods of over 20 years from Weather Bureau (1965)

Station name and period (in years)	Rietfontein (28)	Rooijantjies-fontein (31)	Lichtenburg TNK (57)	Lichtenburg MUN (56)	Leeuwfontein (36)	Welgevonden (34)	Putfontein (31)
January.....(r)	105,3	101,2	109,4	112,3	104,5	99,7	109,5
(d)	10	10	10	10	8	6	10
February....(r)	104,3	105,4	92,2	96,5	89,8	91,4	93,2
(d)	9	9	9	8	7	6	8
March.....(r)	91,5	80,4	92,9	94,0	93,4	86,7	83,6
(d)	9	9	9	8	7	6	9
April.....(r)	45,9	49,5	38,7	36,5	41,6	31,7	31,5
(d)	5	5	5	4	4	2	4
May.....(r)	20,8	19,7	17,7	18,0	21,2	16,8	13,4
(d)	3	3	3	1	2	1	3
June.....(r)	10,6	9,4	6,4	6,9	5,9	7,2	2,8
(d)	1	1	1	1	1	1	1
July.....(r)	5,7	4,7	6,5	6,1	6,5	3,7	6,6
(d)	1	1	1	1	1	1	1
August.....(r)	6,0	5,6	5,1	6,0	2,4	1,9	6,1
(d)	1	1	1	1	1	1	1
September...(r)	14,7	12,3	15,0	14,8	14,3	15,5	12,7
(d)	2	2	2	1	1	1	2
October.....(r)	53,6	42,5	46,2	45,6	40,4	41,2	39,9
(d)	6	5	5	5	5	4	4
November...(r)	69,4	68,5	73,4	69,0	66,8	71,4	64,3
(d)	8	8	8	7	6	5	7
December...(r)	97,0	88,3	98,4	95,2	99,2	80,9	87,4
(d)	9	9	10	9	8	5	9
Year.....(r)	624,8	587,5	601,9	600,9	586,0	548,1	551,0
(d)	64	63	64	56	51	39	59

1.2.6 *Precipitation*

Precipitation within and near the study area is almost entirely in the form of rain, most of which falls during summer. While severe hail storms are experienced with a fairly high frequency, snow is rare. Data from a number of meteorological stations measuring rainfall within the study area are given in Table 1. Mean annual rainfall at Lichtenburg is just over 600 mm, with 85 percent falling during the six summer months from October to March. Rain may be expected to fall on ten days each month during December and January and on only one day per month in winter (Table 1), with an average of about 60 days per year.

1.2.7 *Climate classification and summary*

According to Schulze (1947), the Lichtenburg study area is in the BSkw class of Köppen. The climate is arid (steppe), cold and dry with a mean annual temperature below 18 °C. Mean temperature of the hottest month exceeds 18 °C and the dry season is during winter. Following the Thornthwaite classification (Schulze, 1947; 1958), the study area lies on the border between DB'd to the west and CB'd to the east. DB'd is a semi-arid warm (steppe) climate and CB'd is subhumid warm. In both climates, moisture is deficient throughout the year. Following the classification of UNESCO-FAO (1963) the climate is accentuated temperate tropical. In other words, there is a dry period of between one and eight months coinciding with the period of shortest day-length, the mean temperature of the coldest month is between 0 °C and 10 °C and the xerothermic index is between 150 and 200.

The climate of the study area is summarized in Fig. 2 (modified after Walter & Leith, 1960) and is described by Schulze (1965), on which the following description is based. The average daily maximum temperature is about 28 °C in January and 18 °C in July but in extreme cases temperatures may rise to 37 °C and 25 °C, respectively. Average daily minima range from about 15 °C in January to 2 °C in July, whereas extremes may drop to 6 °C and –10 °C, respectively. The period during which frost is likely to occur lasts, on average, for 106 days from May to September, during which period frost occurs on about 26 days. Sunshine duration in summer is about 60 percent and in winter 80 percent of the possible.

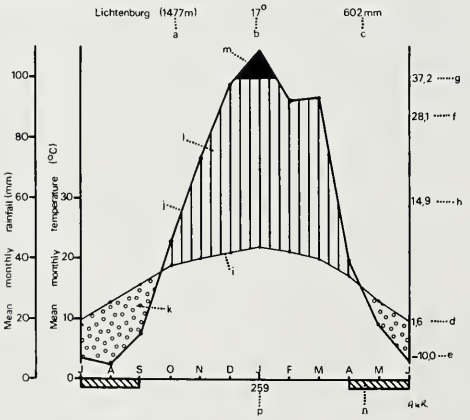


FIG. 2.—Climate diagram for Lichtenburg (a = altitude, b = mean annual temperature, c = mean annual precipitation, d = mean daily minimum temperature of coldest month, e = absolute minimum temperature, f = mean daily maximum temperature of hottest month, g = absolute maximum temperature, h = mean range of temperature, i = curve of mean monthly temperature, j = curve of mean monthly precipitation, k = dry season, l = wet season, m = mean monthly precipitation over 100 mm, n = months with absolute daily minimum temperature below 0°C, p = mean duration of frost-free period in days).

Mean annual precipitation is about 600 mm. Rainfall is almost exclusively due to showers and thunderstorms. Winter months are normally dry and about 85 percent of the annual precipitation falls during the summer months from October to March. A small rainfall peak occurs in January. Heavy falls of 125 mm to 150 mm are occasionally recorded in a few hours. The average annual number of thunderstorms is about 75. These storms are often violent with severe lightning and strong, but short-lived, gusty, south-westerly winds and are sometimes accompanied by hail. The area has a high hail frequency with an average of four to seven occurrences annually.

1.3 *Geomorphology and geology*

1.3.1 *Relief*

The study area lies between 1460 m and 1520 m above sea level. It consists of a large, undulating plain characterised by the absence of any marked topographical features. Gentle rises and shallow hollows throughout, and shallow valleys of the Harts River and its tributaries in the south are the most noteworthy topographical features.

Even in this very monotonous landscape a clear relationship between topography and geology is evident. The south-eastern corner is underlain by by Archaean granite, which forms dome-shaped hills. This slightly-raised portion is part of the divide between the Harts River to the west and Schoon Spruit in the east. The area occupied by Ventersdorp lava, south and south-east of Lichtenburg, is usually devoid of physiographic features. Volcanic brecchia appears in dome-shaped outcrops and volcanic tuff usually forms a featureless topography. The area covered by dolomite, to the north of Lichtenburg, is very flat, being relieved by occasional chert ridges, shallow depressions, dry watercourses and, more frequently, by sink-holes. Surface limestone, west of Lichtenburg, builds extensive flat plains.

1.3.2 *Geological strata*

The geology of the area has been described by Von Backström *et al.* (1953), on which the following account is based.

Although Archaean granite occurs south-east of Lichtenburg, outcrops are rare. It is usually overlain by sandy surface drift.

Deposits of the Ventersdorp system are found in a belt along the southern edge of the area from the south-western corner to a point south of Lichtenburg and then occur again along the eastern boundary of the area. The system consists mainly of andesitic lava. Intercalated are agglomerate and volcanic conglomerate, pyroclastic sediments or tuff and clastic sediments including boulder conglomerate.

Rocks of the Dolomite series of the Transvaal system are, for the most part, covered by more recent deposits, particularly of gravel and surface limestone. Small outcrops occur north and north-east of Lichtenburg, on the boundary of the study area. The Dolomite series consists mainly of blue-grey, massive, dolomitic limestone, with intercalated lenses and layers of chert and shale, the latter being developed more particularly near the base of the Series. In many places dolomite has been weathered chemically and numerous sink-holes are found as a result.

Dwyka series tillite and shale of the Karoo system occur over a fairly wide area south and east of Lichtenburg. Owing to fast weathering and the softness of the formation, rocks are seldom exposed at the surface. Tillite is composed of a soft, clayey, unstratified matrix in which unsorted fragments are spread at random. The fragments are mostly of chert and various quartzites. Examples of glaciated pavements and other distinct signs of glaciation are found.

Economically, the Tertiary and recent deposits are the most important in the area. They consist of gravel, surface limestone, sand and alluvium.

Gravel is found mainly overlying Dolomite series rocks in a belt along the northern edge of the area. The deposits, which vary in depth from a few centimetres to over 50 m, are made up of rounded alluvial material with which is mixed angular, eluvial chert. The alluvial material consists mainly of white, cream-coloured or light grey pebbles of chert and chalcedony although a variety of pebbles derived from other geological systems are also encountered. The eluvial material is composed of angular and irregularly-shaped fragments of chert and concretionary grains of iron, or manganese-iron, derived from weathering of the dolomite floor. Dolomite series rock includes a proportion of very hard, white or grey chert in layers, lenses and veins. As the matrix is dissolved by chemical action, chert remains behind as angular rubble.

Surface limestone covers a large area west of Lichtenburg. It is not generally exposed at the surface, but is covered by a thin, sandy, overburden usually from 20 cm to one metre thick. The thickness of the limestone itself is difficult to determine but it is known to occur as a thin, hard, crust although it is usually much thicker. Depths between 10 m and 38 m have been recorded. The quality of the limestone varies from some of great purity to some that can be described as calcrete. At the surface, the limestone is usually hard and massive while at greater depths it is softer, granular, friable and slightly stratified.

In the area north-west of Lichtenburg the older formations are overlain by red and yellowish Kalahari sand, consisting in the main of slightly rounded grains of quartz, less than one mm in diameter. South-east of Lichtenburg, coarse-grained sand covers a fairly extensive area. It consists of subangular grains of quartz and felspar with flakes of mica and is mainly derived from underlying Archaean granite.

1.3.3 *Erosion surfaces*

Erosion surfaces of the Highveld Agricultural Region have been mapped by Harmse (1967). Dolomite, and gravels overlying dolomite, north of Lichtenburg are of the Karst structural phase of the African surface. Sand overlying the rest of the study area is of the aggradational phase (aeolian sand) of the African surface. Sand was transported from the north-west.

1.3.4 *Economic geology*

As the surface mining of diamonds and limestone within the study area influence the natural vegetation, these activities are described briefly.

The first diamond in the Lichtenburg district was discovered during 1921, although diamonds were being mined in the South-western Transvaal before 1914 (Wagner, 1914; Du Toit, 1951; Draper, 1928; Williams, 1930). As diamond discoveries increased at Lichtenburg, more and more fortune hunters arrived and many spectacular 'rushes' were held, culminating in the famous 'charge' on the farm Grasfontein in March, 1927 when some 25 000 runners participated. In August, 1926, an estimated 56 000 non-Europeans were employed. According to Williams (1930), a population of over 100 000 was resident on the new diamond fields shortly after their discovery. The presence of this large population, concentrated in a small area north of Lichtenburg, must have had a marked effect on the natural vegetation. In addition to direct disturbance by trampling, digging and clearing, the keeping of livestock, gathering of firewood and cultivation of crops probably caused rapid deterioration of vegetation near the diggings. Very little activity is evident on the diggings now and only an occasional miner is encountered.

A large proportion of the area underlain by surface limestone has been purchased by two cement companies with factories in the area. The thin, sandy overburden is bulldozed away and surface limestone is mined by open-cast methods.

1.4 *Soils*

Soils of the 2626AA quarter degree square have been described and mapped by Van der Bank (1968). His map of 17 soil series, four soil complexes and three land classes has been simplified in collaboration with E. Verster (pers. comm.) to eight soil series to conform with present soil nomenclatural concepts of the Soils and Irrigation Research Institute, Pretoria.

The soil survey by Van der Bank (1968) clearly illustrates from one side the differences in emphasis placed by pedologists and plant ecologists in the same area. He describes, in detail, soils which are under heavy cultivation while the Dolomite lithosol receives scant mention. To the botanist, on the other hand, the natural vegetation of the ploughed area is solely of historical interest while the vegetation of the unploughed areas (the lithosols) has great economic and academic value. These differences in emphasis naturally hinder close correlation between results of these and other soil and vegetation surveys of the same area.

1.4.1 *Shorrocks, Mangano and Lichtenburg Series*

Shorrocks series soils occur in small patches north-west of Lichtenburg. Mangano series soils occur very locally within the Dolomite region north of Lichtenburg, while Lichtenburg series soils cover relatively small areas near the Harts River in the south-eastern corner of the study area.

Shorrocks, Mangano and Lichtenburg Series are well-drained soils. They are characterised by good internal drainage and weak structure. They have high, fine sand and low clay content, prominent red colours and an absence of mottling. Horizons that impede drainage are absent. Kaolinite is the principal clay mineral and the exchange capacity varies between two and eight milli-equivalents percent. Calcium and magnesium are the dominant exchange cations throughout the profile.

1.4.2 *Soetmelk Series*

Soetmelk is the non-lithosol series covering the largest area in the quarter degree study area. It occurs throughout the area not underlain by dolomite.

Restricted drainage is a characteristic of Soetmelk soils. With increasing depth the clay content increases and the structure becomes weak medium blocky. Red and yellow mottles associated with uncemented iron concretions are distinctive features of the lower horizons. Principal clay minerals are kaolinite and illite. Montmorillonite tends to increase in the lower

horizons. Exchange capacities vary between four and eight milli-equivalents percent. Calcium and magnesium are the dominant cations.

1.4.3 *Rensburg, Bonheim and Lindley Series*

The Rensburg, Bonheim and Lindley series are poorly-drained soils. Poor permeability, high clay content, high exchange capacity and strong blocky or prismatic structure are the salient features of these Series.

The occurrence of these soils, either collectively or singly, is limited in extent. Rensburg series occurs in the bed of the Harts River while Bonheim series soils are restricted to slopes of the Harts River valley, where the river leaves the dolomite substrate. Lindley series occurs in small patches north and north-west of Lichtenburg. It is usually underlain by dolomite.

1.4.4 *Kalkbank Series*

The feature common to Kalkbank sandy type and Kalkbank loamy type soils is the underlying surface limestone formation encountered at shallow depths. Where the limestone is buried deeper the soil is usually Soetmelk series. The parent materials are either aeolian sand, drift materials, or both.

These soils cover areas of moderate size, usually in complexes, to the west of Lichtenburg.

1.5 *Vegetation*

The vegetation of the study area is described by Acocks (1953) in his survey of the veld types of South Africa (Fig. 3).

In the South-western Transvaal, Dry *Cymbopogon-Themeda* Veld (Veld Type 50) occurs in an arc from Lichtenburg to south-west of Delareyville and then south to Wolmaransstad. This arc, comprising the northern variation of the Veld Type, is found on sandy soils. The dominant species is *Themeda triandra. Cymbopogon plurinodis* is the tallest grass, but is usually not common. This Veld Type lies between altitudes of 1 280 m and 1 370 m on flat, sandy country with a summer rainfall of 430 to 580 mm per annum and with frosty winters. Species of general occurrence are given in Table 2.

Species of less general occurrence include: *Cynodon dactylon, Digitaria argyrograpta, D. eriantha, Panicum coloratum* and *Stipagrostis uniplunis.*

Sandy *Cymbopogon-Themeda* Veld (48) occurs in the rough square bounded by Lichtenburg, Ventersdorp, Klerksdorp and Ottosdal, to the immediate east of the arc of Dry *Cymbopogon-Themeda* Veld. The square comprises the northern variation of the Veld Type where the altitude ranges from 1 310 m to

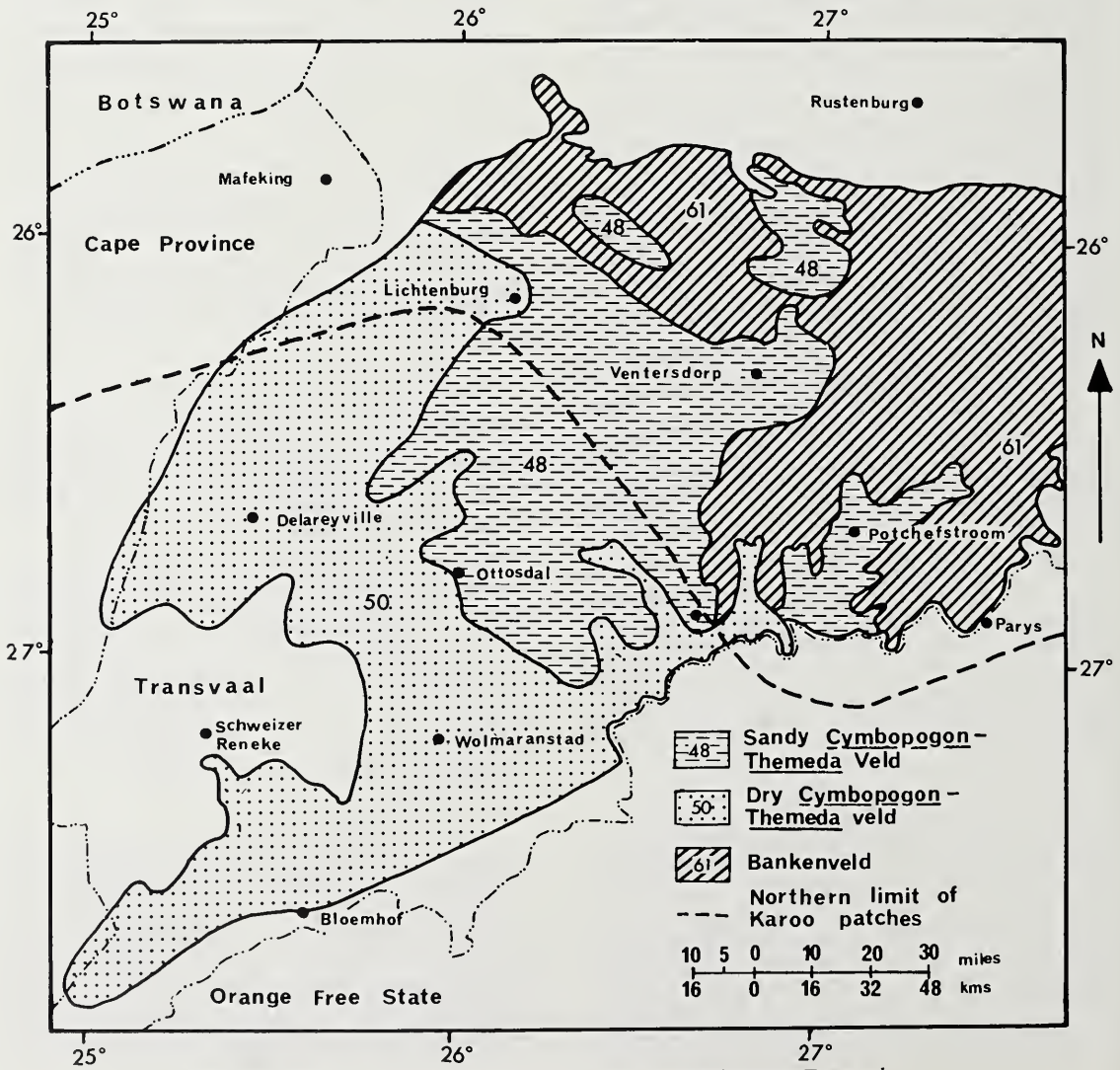


FIG. 3.—Distribution of Veld Types (Acocks, 1953) in the south-western Transvaal.

TABLE 2.—Relative abundance values (in thousands) of those species of general occurrence, according to Acocks (1975), with relative abundances of over 1 000 in Dry *Cymbopogon-Themeda* Veld (50), Sandy *Cymbopogon-Themeda* Veld (48) and Bankenveld (61)

Species	Veld type			
	50	48	61	
Setaria flabellata	142	121	109	Common to all three Veld Types
Heteropogon contortus	7	27	76	
Eragrostis chloromelas	5	20	36	
Elionurus argenteus	11	16	35	
Themeda triandra	165	39	30	
Cymbopogon plurinodis	37	13	13	
Eragrostis racemosa		20	139	Common to Bankenveld and one other Type
Brachiaria serrata		13	15	
Diheteropogon amplectens		1	14	
Triraphis andropogonoides	2		2	
Eragrostis lehmanniana	26			Found in Dry *Cymbopogon-Themeda* Veld
Anthospermum rigidum	8			
Eragrostis superba	7			
Eustachys mutica	5			
Anthephora pubescens	5			
Eragrostis obtusa		2		Found in Sandy *Cymbopogon-Themeda* Veld
Vernonia oligocephala		2		
Eragrostis gummiflua		2		
Eragrostis capensis		1		
Digitaria tricholaenoides			120	Found in Bankenveld
Trachypogon spicatus			15	
Tristachya rehmannii			5	
Justicia anagaloides			5	
Bulbostylis burchellii			5	
Schizachyrium sanguineum			4	
Cassia mimosoides			3	
Senecio venosus			3	
Acalypha angustata			3	
Diplachne biflora			2	
Helichrysum caespititium			2	
Trichoneura grandiglumis			1	

1 520 m and summer rainfall is from 510 to 690 mm. Winters are frosty. Species of general occurrence are listed in Table 2. Species of less general occurrence include *Cynodon dactylon, Cynodon incompletus, Digitaria argyrograpta* and *Helichrysum rugulosum*. According to Acocks, this Veld Type merges into the western variation of Bankenveld and needs more study. Dry *Cymbopogon-Themeda* Veld usually occurs at a slightly lower elevation than Sandy *Cymbopogon-Themeda* Veld and usually receives slightly less rain.

Sandy *Cymbopogon-Themeda* Veld and Dry *Cymbopogon-Themeda* Veld are both Pure Grassveld Types while Bankenveld (61) is a False Grassveld type. Bankenveld occurs in a belt from east of Ventersdorp, to Klerksdorp and Parys. The Western variation occurs near Lichtenburg. It is found on sandy plains and low, rocky ridges, ranging in altitude from 1 370 m to 1 680 m and receives 560 to 690 mm rain, mostly in summer. It is a rather sparse, sour, strongly tufted vegetation and, in the nature of its grasses, is clearly transitional, according to Acocks, from Sandy *Cymbopogon-Themeda* Veld to Sour Bushveld (20), which occurs north of the study area. The climax was possibly an open savanna with *Acacia caffra*. Species of general occurrence are given in Table 2. Species of less general occurrence include *Anthospermum rigidum, Digitaria eriantha, D. monodactyla, Eustachys mutica, Koliautia amatymbica* and *Pygmaeothamnus zeyheri*.

Tentative boundaries to Veld Types drawn by Acocks (1953) for the South-western Transvaal may be re-drawn after more intensive study. Limits of Bankenveld near Potchefstroom and Ventersdorp, east of the study area, have been accurately mapped by Grunow (1959). Photographs from NASA/ERTS-1 flights will greatly aid the further mapping of vegetation in this area at reconnaissance scales. Bankenveld is actually found as far south as Lichtenburg, as far west as a line from Lichtenburg to Mafeking and as far east as a line from Lichtenburg to Rustenburg, although this is not apparent from Acocks's map.

1.6 *Land-use*

Broad land-use categories are closely tied to geology, soils and vegetation in the study area. The parts with deep, well-drained soils overlying all geological systems except dolomite (Dry *Cymbopogon-Themeda*- and Sandy *Cymbopogon-Themeda* Veld Types) are extensively ploughed. Van der Bank (1968) comments that, in practice, all soils that are ploughable have already been ploughed. The principal crop is maize and limited quantities of sunflowers, grain sorghum, groundnuts and cattle fodder are grown. It is estimated by Van der Bank (1968) that the average yield of the maize crop is about 1 170 kg/ha although some farmers reap 1 550 or more kg/ha.

Cattle ranching is the chief occupation of farmers on the dolomitic lithosols (Bankenveld Veld Type) north of Lichtenburg. Occasional sink-holes in the area, which have become filled with aeolian sand, are invariably cultivated for cash crops like maize. Some irrigation, using the good supplies of water from boreholes, is undertaken.

An alarming activity is the open-cast mining of surface limestone in the area by two cement companies. Relatively large tracts of land have been acquired and

are being systematically laid desolate as no attempt appears to have been made to stabilise and re-vegetate stripped areas.

1.7 *CT Grassland and Bankenveld Land Systems*

According to Dowling (1968) and Mabbutt (1968), the land of a region is conceived as a series of Land Systems, each of which contains typical land facets, which have similar features wherever they occur and which can be readily identified on aerial photographs. When relief, geology, geomorphology, soils, vegetation and land-use are considered, two Land Systems may be recognised in the study area. These two Land Systems were treated separately in the sampling and analysis of vegetation reported in this account.

One Land System, named CT Grassland, is underlain by granite, Ventersdorp lavas, Dwyka tillite and surface limestone on the aggradational phase (aeolian sand) of the African erosion surface. Soils of Shorrocks, Mangano and Lichtenburg series are generally sandy and well-drained. The natural vegetation was Dry *Cymbopogon-Themeda* Veld or Sandy *Cymbopogon-Themeda* Veld but most of it has been destroyed for the cultivation of maize, the chief land-use.

The second Land System, named Bankenveld, is underlain by dolomite, variously covered by alluvial gravels on the Karst structural phase of the African erosion surface, and has lithosolic soils. The Veld Type is Bankenveld and cattle ranching is the main land-use.

2. PROCEDURES USED IN THIS STUDY

2.1 *Sampling strategy*

The most important consideration in designing the vegetation sampling strategy was ensurance of compatibility with other component projects of the ecological survey of the Highveld Agricultural Region. A common sampling strategy will enhance possibilities for integration with and extrapolation between individual surveys, including some by other officers. As J. C. Scheepers of the Botanical Research Institute, Pretoria, who is responsible for surveying the eastern half of the Region, had started field sampling before the study reported here was initiated, his general strategy, as outlined below was followed.

2.1.1 *Sample placement and size*

Initially, the 2626AA quarter degree square (Fig. 1) was taken as the study area. All lands under cultivation, or showing signs of past cultivation, as well as the town of Lichtenburg and the bed of the Harts River were excluded from the area to be sampled. The remaining area was stratified into Bankenveld and CT Grassland Land Systems (see 1.7) and physiognomic-physiographic units were delimited on 1:36 000-scale aerial photographs. Morris (1973) details the stratified-random sampling strategy that was used to mark 220 sample positions within the study area and gives reasons for the study area having to be enlarged to that illustrated in Fig. 1. Briefly, insufficient suitable sampling sites were found within the quarter degree square.

The sample size of 4×4 m, chosen during pilot studies for the Highveld Survey Project, was retained for uniformity. Pilot studies had shown that a sample area of 16 m² was both the smallest adequate sample for grassland vegetation of this kind and the largest area that could be sampled in an economically-justifiable time (J. C. Scheepers, pers. comm.). Species present in a belt, approximately two metres wide, around the perimeter of the sample were also recorded to aid re-allocation of samples mis-classified by association analysis owing to the chance absence of a positive dividing species. Details of quadrat location in the field are given in Morris (1973).

2.1.2 *Habitat data*

A limited amount of habitat information was gathered. Physical factors recorded for each site included geology, geomorphology, aspect, angle of slope and exposure. Soil series (Van der Bank, 1968) and depth were recorded and then for each horizon, soil pH, soil reaction to dilute hydrochloric acid (HCl), moist soil colour (Munsell) and soil texture were noted. Biotic influence was noted by animal type and by degree on a four-point scale from absent to very intense.

2.1.3 *Vegetation data*

Total basal cover and height and basal cover of each constituent stratum were estimated for the 16 m² sample and the presence of all permanently-recognisable plant species was recorded. Cover-abundance on the Braun-Blanquet scale (Werger, 1973) was also noted for each species.

2.2 *Association analysis*

At the time of sampling, the only objective method for classifying vegetation known to be suitable was the hierarchical technique of the Southampton-Canberra school (Williams & Lance, 1958; Williams & Lambert, 1959, 1960, 1961; Lambert & Williams, 1962). The original technique, association analysis, has been used by a number of ecologists with varying degrees of success in a number of vegetation types in South Africa, including Van der Walt (1962) in grassland, mountain scrub and karoo vegetation, Grunow (1965a, 1965b, 1967) in bushveld, Downing (1966) in vlei vegetation, Roberts (1966), Miller (1966), Miller & Booysen (1968) and Scheepers (1969) in grassland, Taylor (1969) and Boucher (1972) in fynbos, Downing (1972) in savanna and woodland vegetation and Coetzee (1972) in Bankenveld. Although more advanced analyses had been carried out successfully (for example: Grunow & Lance, 1969), the computer programs were not available in South Africa when the analyses reported here were carried out.

The monothetic-divisive technique of association analysis, used for classification in this account, is so well known as not to require detailed description. Briefly, quadrats to be classified are hierarchically divided on the basis of the presence or absence within each quadrat of the species with the highest association [Chi-squared (χ^2) in one or other form] with every other species. Division by this strategy has been found to remove most heterogeneity from the parent population of quadrats, resulting in groups with a higher degree of homogeneity than any other grouping.

An analysis was carried out on the 220 quadrats (16 m²) of the study area and then another was carried out on the 110-quadrat subset of Bankenveld Land System quadrats. The former, known below as the Total analysis, was done to obtain an overall classification of the vegetation of the area and, in particular, to distinguish the main vegetation types. The second analysis, known as the Bankenveld analysis, was done to obtain more detailed information about Bankenveld, the area whose natural and semi-natural vegetation was of most importance. The Bankenveld analysis was necessary as the Total analysis did not separate the Bankenveld from the CT Grassland Land System clearly enough. In both analyses, the division parameter used was $\Sigma(\chi^2/N)^{\frac{1}{2}}$.

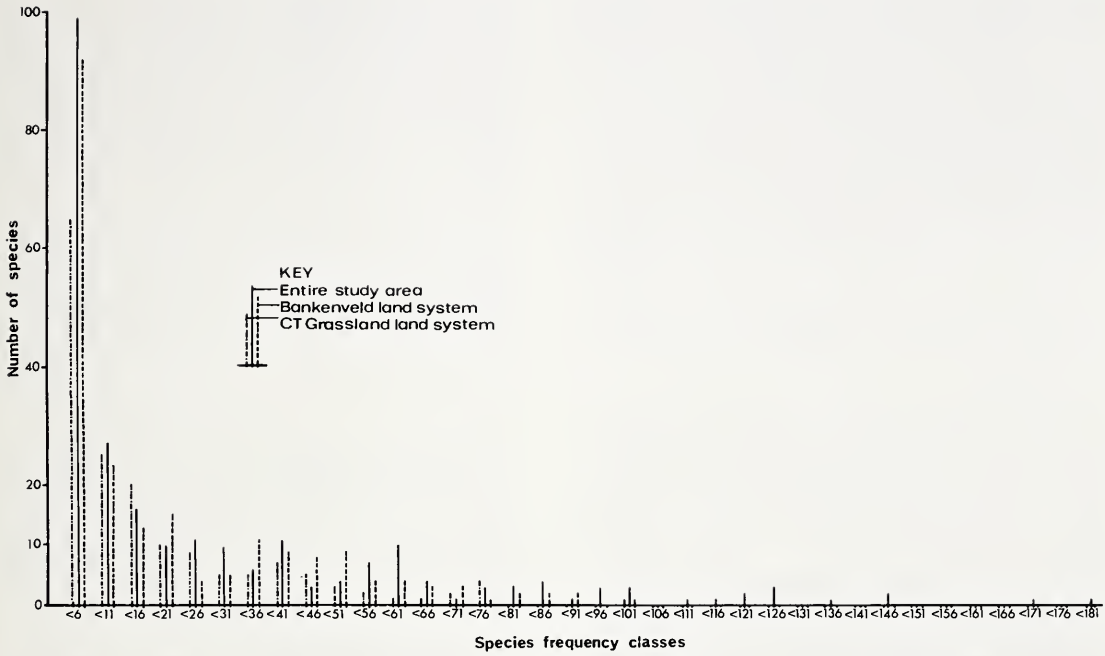


FIG. 4.—Number of species present in each species frequency class over entire study area, within Bankenveld and within CT Grassland Land Systems.

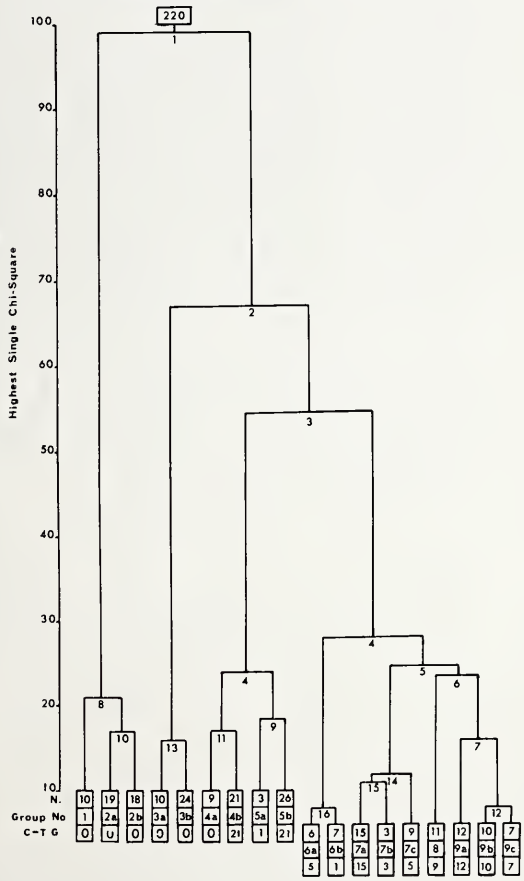


FIG. 5.—Association analysis hierarchy of Lichtenburg study area. N. = total number of quadrats in each group and C—TG is number of CT Grassland Land System quadrats in group. Dividing species are: 1 = *Schizachyrium sanguineum*, 2 = *Kohautia omahekensis*, 3 = *Brachiaria serrata*, 4 = *Stipagrostis uniplumis*, 5 = *Crabbea angustifolia*, 6 = *Heteropogon contortus*, 7 = *Triraphis andropogonoides*, 8 = *Eustachys mutica*, 9 = *Bulbostylis burchellii*, 10 = *Loudetia simplex*, 11 = *Indigofera daleoides*, 12 = *Barleria macrostegia*, 13 = *Eragrostis lehmanniana*, 14 = *Hermannia depressa*, 15 = *Blepharis integrifolia*, 16 = *Vernonia oligocephala*.

Subdivision was terminated when the highest single χ^2 (with Yates's correction) failed to exceed 3,84 (p=0,05), or less than eight quadrats remained in the group. (The neutral term 'group' is preferred to 'association', which has a specific meaning in the Braun-Blanquet sense (Werger, 1973), while other neutral terms like 'community' could have been used). For each analysis, species occurring in fewer than six quadrats were masked as it was presumed that those species were rare enough not to have Indicator value. Their exclusion greatly increased the speed of computation. In each analysis, straight lines were drawn across the hierarchies at fairly low highest single X^2 levels and groups existing at those levels were numbered from left to right. From that level, groups were interpreted downwards to the final groups of the analysis and upwards to the first division.

Although, for economy of reference in the text, groups are usually referred to by numbers and letters, it was required that defined groups be given names as well. The suffix 'Bankenveld' was used to name all groups of the Bankenveld Land System and 'Grassland', 'Woodland' and 'Savanna' suffixes were used for association analysis groups of the CT Grassland Land System. One or two species were chosen for inclusion in the name. Where possible, positive dividing species from the association analysis were used but species with significant Indicator values or high cover-abundance ratings (see later) were also used. In order to create unique names, it was sometimes necessary to overlook a species which appeared suitable as it was even more appropriate for another group.

2.3 *Presence and Indicator value*

Presence and presence percentage were calculated for every species in every group. Presence is the number of times a species occurs in the quadrats of a group and presence percentage is presence expressed as a percentage of the number of quadrats in the group.

Indicator value (Goodall, 1953) for each species was also calculated. Indicator value, according to Goodall, expresses the presence of a species in a particular group against its presence in all other groups.

2.4 *Re-allocation*

Inspection of final groups suggested that because their habitat data were markedly dissimilar from those of other quadrats of the group, certain quadrats were misclassified. By reference to species listed from the area surrounding each 4 by 4 m quadrat they were re-allocated to other groups on the basis of the dividing species of the hierarchy. Some quadrats, which, from inspection, appeared misclassified but which could not be satisfactorily re-allocated by the above method were left in their original groups and are discussed with those groups, as misplaced quadrats.

3. CLASSIFICATION OF THE VEGETATION BY ASSOCIATION ANALYSIS

3.1 *Summary statistics of data*

The total number of species encountered in the 220 quadrats was 247. Within Bankenveld, 211 species were noted, only 36 fewer than in all the quadrats, whereas only 165 species were found in CT Grassland quadrats. Proportions of common and uncommon species are summarised in Fig. 4. The shapes of all three graphs indicate that many species are uncommon (have low overall presence) and that a few species are very common (have high overall presence). Within the entire area nearly 100 species occurred in fewer than six quadrats. Of these, 35 occurred in only one quadrat and 26 in only two quadrats. As nearly 40 percent of the species were uncommon (defined as species occurring in five or fewer quadrats), it was decided to mask uncommon species from the association analyses. Within Bankenveld, 92 species occurred in fewer than six quadrats, 42 species occurred in only one quadrat and 24 were found in only two quadrats.

The commonest species in Bankenveld were *Aristida congesta, Justicia anagaloides* and *Themeda triandra,* occurring in 97, 87 and 86 of the 110 quadrats, respectively. Over the entire study area, *Themeda triandra* was the species occurring most frequently (in 184 quadrats). Other commonly-occurring species were *Aristida congesta* (171 quadrats), *Elionurus argenteus* (150 quadrats), *Anthospermum rigidum* (149 quadrats) and *Justicia anagaloides* (136 quadrats).

A Bankenveld quadrat contained most species (54). In CT Grassland, the highest number of species in a quadrat was 36. In Bankenveld, the lowest number of species was 18, and in CT Grassland it was 11. The average number of species in a Bankenveld quadrat was 36,5 [standard deviation (SD)=7,5] and in CT Grassland the average was 24,3 (SD=5,5). The overall average was 30,4 (SD=9,0).

3.2 *Total association analysis*

3.2.1 *Description of hierarchy*

The association analysis hierarchy classifying all 220 quadrats is given in Fig. 5. The quadrats are divided into four major groups. These four groups are very distinct, being maintained from a level of H.S. $\chi^2>54,0$ (H.S. χ^2 is the abbreviation used for highest single chi-square throughout this account) to H.S. $\chi^2<28,5$ in the case of the third and fourth groups and more than double that amount in the case of the first group. At a level of H.S. $\chi^2 = 20,0$ there are nine groups and at a level of H.S. $\chi^2 = 15,0$ there are 14 groups. At the 14-group level the mean number of quadrats per group is 15,7. Inspection of the results showed that certain subgroups of the fourth major group could be profitably subdivided to a lower level than H.S. $\chi^2 = 15,0$. Thus, divisions above H.S. $\chi^2 = 7,5$ are shown for this major group in Fig 5, where different base lines are used to indicate the two levels of subdivision. As the fourth major group contains more than one third (36 percent) of the quadrats, sub-division to a lower level results in groups that are, in general, not much smaller than those in the other major groups (Table 3).

TABLE 3.—Statistics of major groups

Major group number	No. of final groups	Mean no. of quadrats per final group	SD of mean	Percentage of total no. of quadrats
1.....	3†	15,7	4,9	21,4
2.....	2†	17,0	9,9	15,5
3.....	4†	14,8	10,6	26,7
4.....	9*	8,9	3,6	36,4
4.....	5†	16,0	6,6	36,4

† at H.S. $\chi^2=15,0$
* at H.S. $\chi^2=7,5$

There are three final groups in the first major group, two in the second, four in the third and nine in the fourth major group. The mean number of quadrats in the final groups of each major group is given in Table 3. At H.S. $\chi^2 = 15,0$ the mean number of

quadrats per final group is remarkably similar for the four major groups. The standard deviation of the mean for each major group, however, indicates more variation in number of quadrats per group within the second and third major groups than within the first and fourth groups. At H.S. $\chi^2 = 15,0$ the overall mean number of quadrats per final group is 15,7 with a standard deviation of 0,76. With the finer sub-division of the fourth major group to H.S. $\chi^2 = 7,5$ the mean becomes 12,1 (SD = 3,5).

Groups are numbered from 1 to 9 at the H.S. $\chi^2 = 20,0$ level and further subdivisions are labelled alphabetically and numerically. Groups are usually referred to in the text by number for brevity although, as was mentioned previously, groups are also named after dominant species and appropriate habitat features.

3.2.2 *Re-allocation*

Following the procedure described earlier, quadrat 114, originally in Group 3a, was transferred to 4b, quadrat 112 from 3b to 5b, quadrat 152 from 9a to 7a and quadrat 126 from 9c to 9a. Except where otherwise indicated all results given above and below and including results in all tables and figures relate to groups after re-allocation.

3.2.3 *Interpretation of major groups*

The association analysis did not completely separate Bankenveld from CT Grassland Land Systems. The first two major groups are, however, largely Bankenveld and the last two mainly CT Grassland. Before re-allocation, the first major group consisted of 47 Bankenveld quadrats and no CT Grassland quadrats and the second major group of 34 Bankenveld and two CT Grassland quadrats. After re-allocation, the first two major groups consisted entirely of Bankenveld quadrats. Thus, the presence of either *Schizachyrium sanguineum* or *Kohautia amatiekensis* (the first two dividing species) in a quadrat is a good indication of Bankenveld. The absence of these species does not, however, indicate CT Grassland as 29 of the 110 Bankenveld quadrats also contain neither of these species. Nine of these 29 quadrats make up Group 4a, two occur in Group 5a, five in Group 5b, seven in Group 6, four in Group 7c and two in Group 8. The H.S. χ^2 division levels indicate that quadrats of the first major group are very distinct and are not related to any quadrats outside Bankenveld. The second major group is almost as distinct. The slight admixture of Bankenveld quadrats in the third and fourth major groups suggests that some Bankenveld quadrats are floristically related to some CT Grassland quadrats but that the reverse does not hold.

3.2.4 *Final groups*

As a separate association analysis of Bankenveld quadrats was carried out, a description is not given of the first two major groups and their final groups and of Group 4a, which are made up entirely of Bankenveld quadrats. As presence percentage data are presented in a modified Roman table (Werger, 1973), where groups and species have been shuffled to highlight noda, the following discussion of groups is not strictly in the order in which groups were split off the hierarchy.

(a) Group 4b (Short *Stipagrostis uniplumis* Calcareous Grassland)

Group 4b is the first CT Grassland group to be split off. The quadrats form a homogeneous group with regard to species composition and habitat, with the exception of three quadrats, which are somewhat aberrant with regard to habitat. As it was not possible to re-allocate these three quadrats by reference to the species in the surrounds, they were retained in the Group.

With two exceptions, all quadrats occur on shallow aeolian sand overlying surface limestone. In a few cases the sand deposit is over 30 cm deep, so that the soil may be classified as Soetmelk series, but in general it is a 2,5 to 10 cm deep lithosol. All quadrats are situated on a flat plain with virtually no relief. Soil pH is usually 7,5 but occasionally 7,0 or 8,0. Soil HCl reaction is usually strong or moderately strong in shallow soil and weaker where the soil is deeper. A negative correlation, significant at $p = 0,01$ was found between soil depth (in cm) and HCl reaction recorded on a 0, 1, 2, 3 intensity scale. Grazing was light, or absent, for most quadrats of this Group. In about one third of the quadrats selective grazing was observed and in four quadrats heavy grazing and trampling were recorded. Basal cover data are given in Table 4 together with mean number of species per quadrat. As the overall average number of species per quadrat in CT Grassland is about 24, quadrats of this Group are relatively rich in species. Species commonly occurring in quadrats of Group 4b are listed in Table 4. All species with a presence greater than 39 percent are listed and species with lower presence but positive, significant Indicator values are also included. *Brachiaria serrata, Stipagrostis uniplumis* and *Themeda triandra* occur in all 21 quadrats of the Group. Possible indicator species, i.e. species which are common within the Group but are uncommon through the rest of the study area, include *Fingerhuthia africana, Geigeria burkei* and *Convolvulus ocellatus* var. *ornatus,* although the latter is present in only 12 of the quadrats of the Group.

(b) Group 6 (Tall *Stipagrostis uniplumis* Calcareous Grassland)

Group 6 is a small group of 13 quadrats, of which six were located in CT Grassland. All the quadrats are located west of Lichtenburg, some near the town and some as far as 25 km away. All but one of the quadrats occur on flat plains underlain by surface limestone deposits. Slope is negligible and sites are very exposed. One quadrat occurs on a flat plain where sand, over 100 cm deep, overlies dolomite and gravels of the Transvaal System.

Soil over the limestone is sandy and usually 30 to 50 cm deep. Soil pH is 7,0 or 7,5 and soil HCl reaction is slight or absent. Grazing was usually light and average total basal cover for both strata was 13,7 percent. While *Stipagrostis uniplumis* is the only species occurring in all six CT Grassland quadrats of Group 6 (Table 4), the Group is too small for any Indicator values to be significant. Both *Stipagrostis uniplumis* and *Themeda triandra* reach high cover-abundance values in quadrats of this Group. No species with a presence of over 49 percent is restricted in distribution to quadrats of this group.

(c) Similarities between Groups 4b and 6

Groups 4b (Short *Stipagrostis uniplumis* Calcareous Grassland) and 6 (Tall *Stipagrostis uniplumis* Calcareous Grassland) have many features in common. In addition to the similarity of dividing species (Fig. 5), these Groups share the same geological substrate, geomorphology and soils. Soils are, however, slightly deeper in Group 6 and HCl reaction is only slight, or absent, in contrast with the strong or moderately strong reaction in Group 4b. Mean basal cover of the tall grass stratum in Group 6 was double that in Group 4b. The mean number of species per quadrat

TABLE 4.—Mean number of species per quadrat and mean basal cover by stratum and presence percentage of common species in each group where arrangement of species and groups follows a Braun-Blanquet Roman Table order. X indicates a high cover-abundance rating for the species in most, if not all, quadrats of the group and a dash (—) indicates a value of less than 40%

Group	4b	6	5b	8	7b+c	7a	9a i	9a ii	9b	9c
Mean no. of species/quadrat	26,3	26,3	26,5	23,1	23,6	26,4	21,8	22,0	20,7	15,2
Standard deviation of mean	4,9	7,4	5,2	4,4	3,1	4,5	5,2	11,0	2,1	3,7
Mean basal cover: total %	9,4	13,7	8,4	10,4	7,5	9,1	6,3	8,3	5,4	6,2
tall stratum %	3,8	8,0	2,2	4,0	2,0	2,7	1,7	2,8	1,0	1,6
short stratum %	5,5	5,7	6,3	6,4	5,5	6,4	4,5	5,5	4,4	4,6
SPECIES										
Geigeria burkei	48	—	—	—	—	—	—	—	—	—
Euphorbia sp (M & B 70)*	38	—	—	—	—	—	—	—	—	—
Selago holubii	33	—	—	—	—	—	—	—	—	—
Wahlenbergia caledonica	33	—	—	—	—	—	—	—	—	—
Salvia radula	29	—	—	—	—	—	—	—	—	—
Scabiosa columbaria	29	—	—	—	—	—	—	—	—	—
Mariscus capensis	24	—	—	—	—	—	—	—	—	—
Stipagrostis uniplumis	100X	100X	—	—	—	—	—	—	—	—
Fingerhuthia africana	71	50	—	—	—	—	—	—	—	—
Convolvulus ocellatus var. ornatus	57	50	—	—	—	—	—	—	—	—
Brachiaria serrata	100	—	100	—	—	—	—	—	—	—
Dicoma anomala	81	—	55	—	—	—	—	—	—	—
Aristida diffusa var. burkei	76X	—	60	—	—	—	—	—	—	—
Chascanum hederaceum	—	—	40	—	—	—	—	—	—	—
Helichrysum zeyheri	—	—	30	—	—	—	—	—	—	—
Heteropogon contortus	48	—	95	100	75X	—	—	—	—	—
Hibiscus microcarpus	—	—	50	67	—	—	—	—	—	—
Lasiosiphon capitatus	—	—	50	56	—	—	—	—	—	—
Gazania krebsiana	—	—	45	44	—	67	—	—	—	—
Hermannia betonicifolia	—	50	—	56	—	—	—	—	—	—
Nolletia ciliaris	—	50	—	44	—	—	—	—	—	—
Pogonarthria squarrosa	—	—	—	56	—	—	—	—	—	—
Cymbopogon excavatus	—	—	—	44	—	—	—	—	—	—
Raphionacme hirsuta	—	—	—	44	—	—	—	—	—	—
Diplachne fusca	—	—	—	56	50	—	—	—	—	—
Acalpyha sp. (M & E 1267)*	48	—	—	—	50	—	—	—	—	—
Cassia mimosoides	—	—	—	—	50	—	—	—	—	—
Hypoxis sp. (not collected)	—	—	—	—	50	—	—	—	—	—
Aristida canescens	—	—	35	—	—	73X	—	—	—	—
Helichrysum caespititium	—	—	—	44	—	67	—	—	—	—
Crabbea hirsuta	—	—	—	—	—	53	—	—	—	—
Eragrostis stapfii	—	—	—	—	—	47	—	—	—	—
Euphorbia pseudotuberosa	—	—	—	—	—	47	—	—	—	—
Rhynchosia totta	—	—	—	—	—	40	—	—	—	—
Euphorbia inequilatera	76	—	—	—	—	53	—	67	—	—
Corchorus asplenifolius	76	—	—	—	—	47	—	—	—	—
Thesium costatum	43	—	—	—	—	—	56	—	—	—
Dicoma macrocephala	—	—	—	—	—	—	44	—	—	—
Lippia scaberrima	—	—	—	—	—	—	67	—	90	—
Brayulinea densa	—	—	—	—	—	—	—	—	50	—
Lasiocorys capensis	—	—	—	—	—	—	—	—	50	—
Antizoma angustifolia	—	—	—	—	—	—	—	—	40	—
Panicum coloratum	—	—	—	—	—	—	—	—	—	71
Acacia karroo	—	—	—	—	—	—	—	—	—	43
Aptosimum indivisum	—	—	—	—	—	—	—	—	—	43
Blepharis integrifolia	—	—	—	—	—	100	78	100	70	71
Eragrostis lehmanniana	—	—	—	—	—	60	78X	67X	50	57
Hermannia depressa	—	—	—	44	—	100	56	67	40	—
Hibiscus pusillus	—	—	—	—	—	60	—	67	40	57
Felicia muricata	—	—	—	—	—	53	—	—	90	43
Sporobolus africanus	—	—	—	—	—	—	67	—	90X	71
Solanum supinum	—	—	—	—	—	—	78	67	70	—
Setaria flabellata	—	—	85	89	63X	80	56	67	40	71
Eragrostis curvula	—	—	65	89	75	87	67X	100X	70X	71X
Cymbopogon plurinodis	—	—	50	—	75	80X	44	100X	40	—
Digitaria argyrograpta	—	—	45	67	—	47	89	—	40	86X
Justicia anagaloides	—	—	85	44	63	40	44	—	—	—
Eragrostis gummiflua	—	—	40	56	—	—	78X	—	—	—
Eustachys mutica	—	—	—	67	50	80	89X	100X	—	57
Cynodon dactylon	—	—	—	—	50	—	44X	—	90X	71
Themeda triandra	100X	83X	95	78	100X	100	89	100	60	71X
Aristida congesta	—	83	70	89	75	67	100	67	80	43
Elionurus argenteus	81X	67	90X	67X	50X	87X	—	100X	40	—
Barleria macrostegia	67	67	65	67	50	93	—	100	100	—
Anthospermum rigidum	43	67	85	89	88	73	44	—	40	—
Triraphis andropogonoides	62	—	65	67	88	60	89X	100X	—	—
Eragrostis superba	—	67	—	—	—	73	78	—	80	—
Crabbea angustifolia	76	—	70	—	100	93	—	—	—	—
Vernonia oligocephala	—	83	50	—	63	—	—	—	—	—
Total number of species	24	24	12	28	19	24	21	15	22	15

* Specimens of Morris & Boucher 70 and Morris & Engelbrecht 1267, housed in National Herbarium, Pretoria.

was the same in both Groups. Three species, *Stipagrostis uniplumis, Fingerhuthia africana* and *Convolvulus ocellatus* var. *ornatus* were common in these two Groups but nowhere else.

Most of the area formerly occupied by Short and Tall *S. uniplumis* Calcareous Grassland has been ploughed for maize cultivation. Most of the rest, where the soil is too shallow for ploughing, has been excavated to supply limestone for local cement factories or has, at least, been bought for this use in future. The area covered by Tall and Short *S. uniplumis* Calcareous Grassland is decreasing rapidly as a result of this activity.

(d) Group 5b (*Elionurus argenteus* Secondary Grassland)

As Group 5b is the last group of the third major group of the hierarchy, a certain amount of heterogeneity in floristics as well as in habitat was expected. Heterogeneity will be apparent from the description which follows.

Quadrats of this Group occur in three main clusters north-west, north-east and south of Lichtenburg, respectively. Various geological substrates underlie quadrats of this Group. Half are underlain by Ventersdorp lava, quartzites, brecchia or conglomerate, four are on deep sand overlying dolomite and chert of the Transvaal system and two quadrats each are found on surface limestone, Archaean granite and Dwyka tillite. Three quadrats face north on very gentle slopes and the others occur on flat plains or crests of hills. Half the quadrats in this Group have soil over 80 cm deep and the rest are on shallower soil with an average depth of 15 cm. All quadrats are found on Soetmelk soil series. Soil pH is usually 6,5 but values of 6,0 or 7,0 are occasionally recorded. Biotic influence varied widely. Some quadrats were only lightly grazed while others were heavily grazed and some showed signs of soil erosion. All heavily-grazed quadrats were located on deep soil while only light grazing was recorded on shallow soils. Mean total basal cover was slightly lower than in Group 4b and mean number of species per quadrat was almost the

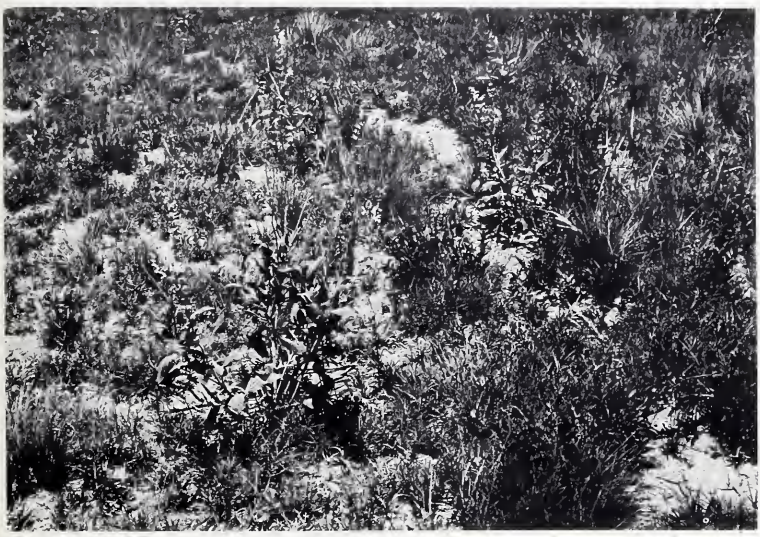


FIG. 6.—*Salvia radula*, 50 cm tall, in Short *Stipagrostis uniplumis* Calcareous Grassland. Grasses include *S. uniplumis*, *Brachiaria serrata*, *Themeda triandra*, *Aristida diffusa* var. *burkei* and *Elionurus argenteus*. Hendriksrust, Lichtenburg District.



FIG. 7.—Desolation of an abandoned, flooded open-cast calcrete mine. Plant colonisation of such areas is slow. This site was previously *Stipagrostis uniplumis* Calcareous Grassland. East of Lichtenburg on Town Lands.

same in both groups (Table 4). Species commonly occurring in quadrats of Group 5b are listed in Table 4. Only *Brachiaria serrata* occurs in all quadrats. *Elionurus argenteus,* after which the Group is named, is the only species with high cover-abundance in many quadrats of the Group. No species with high presence percentage have significant Indicator values. Only *Chascanum hederaceum* and *Helichrysum zeyheri* are not recorded in the floristic summary of any other group.

(e) Group 8 (*Elionurus argenteus* Primary Grassland)

Quadrats of Group 8 occur mainly at two places, east of and west of Lichtenburg, respectively.

Five quadrats occur on Ventersdorp conglomerate, lava or quartzites, three on sand overlying dolomite and gravels and one on Dwyka tillite. Quadrats are on extensive flat plains or on gentle waxing slopes. The soils developed from the three rock types all belong to Soetmelk series. Soils are usually 60 cm to over one metre deep, soil pH is usually between 6,5 and 7,0 and no soil HCl reaction is recorded. With only one exception, the quadrats of this Group were not grazed or were only lightly grazed and in good condition. Species present in more than 39 percent of the quadrats of Group 8 are listed in Table 4.

Heteropogon contortus is the only species occurring in all 9 quadrats of this Group. The Group is too small for any indicator values to be significant. High cover-abundance values were only rarely recorded for species in quadrats of this Group. In addition to the widespread grass, *Elionurus argenteus, Eragrostis gummiflua* and *Eustachys mutica* were the only species with high cover-abandance values in three or more quadrats.

(f) Similarities between Groups 5b and 8

Groups 5b (*Elionurus argenteus* Secondary Grassland) and 8 (*Elionurus argenteus* Primary Grassland) have a number of features in common and the reason for the association analysis split is not clear. Most quadrats of both Groups are found on rocks of the Ventersdorp System, on flat plains and where the soil series is Soetmelk. In Group 5b, half the quadrats are on shallow soil (mean depth 15 cm), while the other half are on deeper soil (over 80 cm) while in Group 8, soils are usually over 60 cm deep. Soil pH and HCl reaction are similar in the two Groups. In Group 5b, quadrats on the deeper soils were heavily grazed while quadrats on the shallower soils were rested or only lightly grazed. In Group 8, where the soil is generally deep, grazing is light or the vegetation has been rested. One of the main differences is, thus, a disturbance factor of grazing pressure interacting with the occurrence of shallow soil, resulting in the names 'primary' and 'secondary' for these *Elionurus argenteus* Grasslands. Basal cover of the tall grass stratum is slightly higher in Group 8 than in Group 5b but cover of the short grass stratum is the same. A slightly greater number of species occur in quadrats of Group 5b than in those of Group 8. *Hibiscus microcarpus* and *Lasiosiphon capitatus* were the only species which occurred commonly in these two Groups and nowhere else. Nine species (Table 4) occurred in over 60 percent of the quadrats of both Groups 5b and 8. Species which are common in Group 5b (in over 60 percent of the quadrats) but are either rare in, or do not occur in Group 8 (less than 60 percent of the quadrats) include *Brachiaria serrata* (the dividing species between the two groups), *Aristida diffusa* var. *burkei, Crabbea angustifolia* and *Justicia anagaloides. Eustachys mutica* is the only species found in over 60 percent of the quadrats of Group 8 and in fewer than 40 percent of the quadrats of Group 5b.

(g) Group 7

Fifteen quadrats of Group 7, defined by the presence of both *H. depressa* and *B. integrifolia,* form a distinct Group, 7a, made up entirely of CT Grassland quadrats (Fig. 5). The Group defined by the absence of *B. integrifolia,* 7b, contains only three quadrats and as it appears related to Group 7c, it is discussed with it.

Quadrats of Groups 7b and 7c occur scattered through the study area. Floristic parameters are summarised in Table 4. The quadrats are found on a number of geological substrates and soil series. Three quadrats are located on surface limestone (Soetmelk soil series), three on sand overlying dolomite and gravels (Soetmelk series), one on granite and one on Ventersdorp brecchia and conglomerate. All are on exposed, flat sites. In most quadrats, grazing was light or the vegetation had been rested for some time before sampling. Heavy grazing was recorded from two quadrats. Species occurring in more than three of the eight CT Grassland quadrats of these Groups are listed in Table 4. Only two species, *Crabbea angustifolia* and *Themeda triandra* occur in all eight quadrats. *Themeda triandra, Heteropogon contortus* and *Setaria flabellata* had high cover-abundance

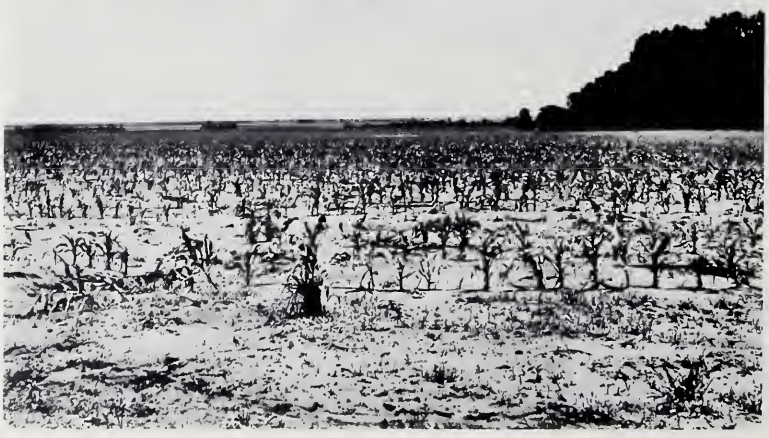


Fig. 8.—Extensive maize cultivation in CT Grassland Land System. This area was *Elionurus argenteus* Grassland before cultivation. Exotic *Eucalypus* sp. shown on right, shallow valley of Harts River in middle distance and town of Lichtenburg on horizon. Rietgat, Lichtenburg District.

estimates in most quadrats of the Groups. The combined Group is too small for any Indicator values to be significant.

Groups 7b and 7c do not form distinct units. As a number of quadrats apparently belonging to other Groups appear to be included in these Groups, evidenced by the lack of uniformity in habitats, and as they are small groups, they are not named.

Only one quadrat (120) appears mis-classified in Group 7a (*Cymbopogon plurinodis* Grassland). As it could not be re-allocated by reference to the species in the surround, it was left in the Group. Quadrat 152 was re-allocated to this Group from 9a. Quadrats of Group 7a occur in two clusters near each other. One cluster borders Lichtenburg to the south-east and the other is east of the town. With the exception of quadrat 120, quadrats of this Group are located on flat plains underlain by Dwyka tillite. Slope is one percent or less and sites are exposed. The soil series in all quadrats is Soetmelk. Average soil depth is about one metre and soil pH is 7,5 or 8,0. A slight soil HCl reaction is occasionally recorded. On the other hand, quadrat 120 occurs in a slight hollow on a flat plain covered with surface limestone. The soil series is Kalkbank. Soil depth is about 40 cm with a pH of 7,5 and no soil HCl reaction. Within Group 7a, biotic influence was most variable. Some quadrats enjoyed total protection from grazing, as within the Lichtenburg aerodrome reserve, while others in the municipal commonage were heavily grazed and trampled. All species with a presence exceeding 39 percent in quadrats of Group 7a are listed in Table 4. *Blepharis integrifolia, Hermannia depressa* and *Themeda triandra* occur in all 15 quadrats. High cover-abundance values were recorded for *Elionurus argenteus, Cymbopogon plurinodis* and *Aristida canescens. Eragrostis stapfii, Rhynchosia totta, Euphorbia pseudotuberosa* and *Crabbea hirsuta* are not common enough to be included in the floristic summary of any other Group.

(h) Group 9

Twelve quadrats are split off Group 9 at H.S. $\chi^2 = 16,0$ to form Group 9a, within which two slightly different subgroups (9a i and 9a ii) are recognised. Group 9c is the last group of this analysis and is defined by the absence of all dividing species. Quadrat 126 was re-allocated from Group 9c to the first subgroup of 9a and quadrat 152 was re-allocated from the first subgroup of 9a to Group 7a on the bases of species recorded in the surrounds of these quadrats. Subgroups of Group 9 have a number of features in common. Most of the quadrats are on Ventersdorp system rocks. The soil is usually deep with a pH of 6,0 or 7,0. In nearly all quadrats, grazing was heavy and trampling was recorded. Grass basal cover was low and the mean number of species per quadrat was about 20, the lowest of any group of the analysis.

Quadrats of Group 9a (*Acacia karroo* Savanna) (9a i) and Secondary *Cymbopogon plurinodis* Grassland (9a ii) occur scattered through the area east of Lichtenburg. Four quadrats occur together with a cluster of Group 9c quadrats. One quadrat (126), which was re-allocated to this Group, occurs west of Lichtenburg and differs from the rest of the Group in other respects as well.

Quadrats of the first subgroup of Group 9a (9a i), named *Acacia karroo* Savanna, occur on Ventersdorp quartzites while those of the second subgroup (9a ii), named Secondary *Cymbopogon plurinodis* Grassland, are found on Dwyka tillite substrate. Quadrat 126, the aberrant, re-allocated quadrat, occurs on a surface limestone deposit. Quadrats of the first subgroup occur on extensive flat plains or on waning slopes to streams while those of the second subgroup occur on flat plains or waxing slopes. In all cases, slopes are very slight (one degree or less). About half the quadrats are moderately-exposed and half are exposed.

A number of soil series are represented in the first subgroup, including Lichtenburg, Soetmelk and Rensburg, while all three quadrats of the second subgroup are on Soetmelk series. Soils are relatively deep, averaging about 90 cm. Soil pH varies between 6,0 and 7,0 and no soil HCl reaction is recorded. In all the quadrats of this Group, grazing was heavy and the vegetation had been trampled. Trees were invading grassland at a number of Group 9a i sites. The most common tree was *Acacia karroo* which occurred as a seedling or full-grown tree up to 4 m tall. *Ziziphus mucronata* occurred occasionally as well as the following shrubs: *Asparagus laricinus, Diospyros lycioides* and *Maytenus heterophylla.*

Basal cover was low in quadrats of Group 9a i. Average total basal cover was only 6,3 percent. Mean number of species per quadrat in both subgroups was about 22,0. Species present in more than 39 percent of the quadrats of Group 9a i are listed in Table 4. *Aristida congesta* is the only species occurring in all quadrats of the Group. *Eustachys mutica, Triraphis andropogonoides, Eragrostis gummiflua, E. lehanniana* and *E. curvula* have high cover-abundance estimates in most quadrats of the Group. Species present in more than one of the three quadrats of Group 9a ii are listed in Table 4. As there are only three quadrats in the Group, these presence values should not be relied on. Both Groups 9a i and 9a ii are too small for any Indicator values to be significant. Species which are more common in Group 9a i than Group 9a ii include: *Digitaria argyrograpta, Eragrostis gummiflua, E. superba, Lippia scaberrima, Thesium costatum* and *Sporobolus africanus.* As Group 9a ii is so small, species presence in it are not known accurately. The following species, however, appear more common in Group 9a ii than in 9a i: *Cymbopogon plurinodis, Elionurus argenteus, Euphorbia inequilatera, Barleria macrostegia* and *Hibiscus pusillus.*

There are many similarities between Group 7a (*Cymbopogon plurinodis* Grassland) and Group 9a ii (Secondary *Cymbopogon plurinodis* Grassland). Group 9a ii is, however, too small for a detailed ecological analysis and interpretation. The two Groups have geological, geomorphological and soil characteristics in common. Soils are slightly shallower in Group 9a ii than in Group 7a. Biotic influences were variable in Group 7a but grazing was heavy and trampling marked in Group 9a ii. Mean basal cover and number of species per quadrat were lower in the latter Group. As grazing and trampling are generally more severe in Group 9a ii than in 7a, the former Group is called Secondary *Cymbopogon plurinodis* Grassland and the latter, *Cymbopogon plurinodis* Grassland.

Quadrats of *Acacia karroo* Open Woodland (Group 9b) are distributed in two clusters, south and south-east of Lichtenburg, respectively. Nine of the ten quadrats of this Group are situated on Ventersdorp System rocks. Ventersdorp lava, conglomerate, brecchia and quartzites are represented. The remaining quadrat is located on granite. Most of the quadrats are located on flat plains or the crests of hills where slope is too slight to measure. Most of the quadrats are sheltered or moderately sheltered, in marked contrast to the quadrats of other groups described above. Sheltering is usually by the presence of trees in, or near, the quadrats. Soetmelk series, Soetmelk lithosol and Lichtenburg series are the most common soils recorded

for these quadrats. Soil is usually 60 cm to one metre deep with a pH of 6,0 to 6,5. Nearly all the quadrats showed signs of heavy grazing and trampling. The condition of the vegetation of even those quadrats in which grazing appeared moderate was recorded as being poor, probably as a result of heavy grazing in the past.

Basal cover in quadrats of Group 9b was low. Total average basal cover was only 5,4 percent. The number of species per quadrat was low, the average being 20,7 and 24 being the highest number of species recorded in a quadrat of the Group. Species present in more than 39 percent of the quadrats of Group 9b are listed in Table 4. *Barleria macrostegia* is the only species occurring in all ten quadrats. *Brayulinea densa* and *Lasiocorys capensis* have significant Indicator values. High cover-abundance was recorded for *Cynodon dactylon, Sporobolus africanus* and *Eragrostis curvula* within the Group. Trees and shrubs are recorded from the surrounds of six quadrats. The most common tree is *Acacia karroo,* which attains a height of 4,5 to 6 m. Occasional, or co-dominant with *A. karroo* is *A. caffra.* Other trees found occasionally include *Celtis africana* (7,5 m), *Ziziphus mucronata* (5,5 m), *Acacia robusta* (rare) and *Rhus lancea.* In *Acacia karroo* Open Woodland the trees are usually one to three crown-diameters apart. Shrubs include *Maytenus heterophylla,* which can encroach on shallow soil with mismanagement, *Xeromphis rudis, Grewia flava* (occasional, or common, in understorey), *Asparagus laricinus* and *Diospyros lycioides.*

Six quadrats of Drainage Basin *Acacia karroo* Open Woodland (Group 9c) are located east of Lichtenburg along a tributary of the Harts River. The other quadrat (183) occurs south-east of Lichtenburg with quadrats of Groups 9a and 9b. Although the bed of the Harts River was not sampled, the whole drainage basin is probably covered by this Woodland. The geological formation underlying all the quadrats is Ventersdorp series quartzites. Two quadrats are on flat plains, four on waning slopes to drainage lines and one is in a drainage basin. Most quadrats are north-facing on gentle slopes. Four of the quadrats are sheltered by having trees in and near them.

A number of soil series are represented in Group 9c. Three quadrats are on Rensburg series alluvial clay, two on the transition between Rensburg and Soetmelk series and two on Lichtenburg series. Soils are usually one metre deep and pH varies between 6,0 and 7,0. Soil HCl reaction is recorded from two quadrats. Heavy grazing and trampling were recorded for five of the quadrats but in two quadrats the vegetation was in good condition and grazing had been light. Total basal cover was low (6,2 percent), but slightly higher than in Group 9b. The mean number of species per quadrat was by far the lowest value for this analysis. Species present in more than 39 percent of the quadrats of Group 9c are listed in Table 4. *Digitaria argyrograpta,* in six of the seven quadrats, is the most common species. *D. argyrograpta, Eragrostis curvula* and *Themeda triandra* have high cover-abundance estimates in quadrats of the Group. Three species, *Panicum coloratum, Acacia karroo* and *Aptosimum indivisum* are not listed as present in any other group of the analysis (Table 4). Trees and shrubs, similar to those of Group 9b, were recorded from four quadrats.

Individually, Groups 9b and 9c are too small to produce many significant Indicator values. Considering that they are the last Groups of the analysis, however, a surprising number of significant Indicator values are found in the combined Group. Seven species (*Felicia muricata, Digitaria argyrograpta, Lippia scaberrima, Solanum supinum, Hibiscus pusillus, Panicum coloratum* and *Brayulinea densa*) out of the 18 species occurring in more than five of the 17 quadrats of the combined Group have significant Indicator values. *Cynodon dactylon, Sporobolus africanus* and *Eragrostis curvula* have high cover-abundance estimates in quadrats of the combined Group.

3.3 *Bankenveld association analysis*

3.3.1 *Description of hierarchy*

The association analysis hierarchy resulting from classification of the 110 Bankenveld Land System quadrats is given in Fig. 11. The first three divisions yield four distinct major groups, labeled A to D for



FIG. 9.—Four metre tall *Acacia karroo* trees in *Acacia karroo* Open Woodland. Rietgat, Lichtenburg District.



FIG. 10.—Harts River in flood, January 1976. Trees on banks are mostly exotic *Salix* and *Eucalypus* species. Floodplain grassland of Drainage Basin *Acacia karroo* Open Woodland in foreground. Rietgat, Lichtenburg District.

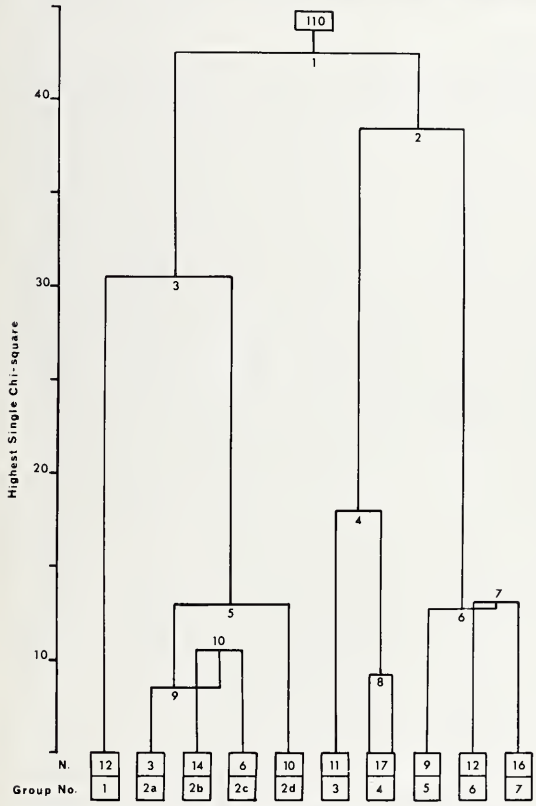


FIG. 11.—Association analysis hierarchy of Bankenveld Land System. Dividing species are: 1 = *Diheteropogon amplectens*, 2= *Chascanum hederaceum*, 3 = *Stipagrostis uniplumis*, 4 = *Eragrostis racemosa*, 5 = *Sporobolus pectinatus*, 6 = *Ursinia nana*, 7 = *Oropetium capense*, 8 = *Schizachyrium sanguineum*, 9 = *Corchorus asplenifolius*, 10 = *Heteropogon contortus*.

convenience. The first Group, A, is small, consisting of only 12 quadrats. It is very homogeneous with regard to species associations as it does not divide from H.S. $\chi^2 > 30,0$ until H.S. $\chi^2 = 7,2$. In addition to being a major group it is also Final Group 1. Group B contains 33 quadrats. At H.S. $\chi^2 = 8,0$ it is divided into four Final Groups, named 2a, 2b, 2c and 2d. Group C contains 28 quadrats and is divided into two Final Groups at H.S. $\chi^2 = 15,0$. Three Final Groups are obtained from major Group D, which contains 37 quadrats. Final Groups in A and B were obtained by terminating division at H.S. $\chi^2 = 8,0$ and final groups C and D by terminating division at H.S. $\chi^2 = 10,0$. These levels were chosen arbitrarily, for naming purposes, and divisions below these levels are discussed at appropriate places in the text.

Based on hierarchy division levels (H.S. χ^2), Groups A and B, on the one hand, are most dissimilar from Groups C and D on the other. Groups C and D differ more from each other than does Group A from B, as the former divide further at a higher H.S. χ^2 than the latter. The small number of splits above H.S. $\chi^2 = 15,0$, at which level there are only five groups, suggests that the sample consists of a few, large groups, which are rather homogeneous. The homogeneity of A has already been mentioned. Major Groups C and D are also homogeneous, the former being maintained from H.S. $\chi^2 > 35,0$ to H.S. $\chi^2 = 18,0$ and the latter from H.S. $\chi^2 > 35,0$ to H.S. $\chi^2 = 12,7$.

The mean number of quadrats in each final group is fairly constant. Fewest quadrats are found in Final Groups 2a, 2b, 2c and 2d (8,2 average). On average, twelve quadrats are found in each final group of major Groups A and D. The average number of quadrats in Final Groups 3 and 4 is 14,0.

Re-allocation was not required in this analysis and the few quadrats which do not fit the description of a particular group as a whole are discussed in the group description.

Group 7 is the last group of the hierarchy and is defined by the absence of all dividing species. Quadrats of this group do not form a meaningful unit, being scattered diffusely across the northern and southern boundaries of the area. This group is neither named nor discussed further as it is considered a collection of quadrats which should have been included in other groups but which, by chance, lacked the necessary defining species. Re-allocation of these quadrats was not considered worthwhile.

3.3.2 *Species distribution within groups*

When lists of species commonly occurring in each final group were drawn up as part of the interpretation of each group, it was found that large numbers of species seemed common to many groups and that there were few species that were restricted to only one or two groups. To study these findings at greater depth, a species-in-groups Table was drawn up. Five Final Groups, namely 1, 3, 4, 5 and 6 and Group B (consisting of Final Groups 2a, 2b, 2c and 2d) were used for the six columns of the Table. The presence percentage of every species in each group

was computed and rows of the Table were then formed by the 84 species, each of which had a presence of over 39 percent in at least one group. These presence percentages are given in Tables 5 and 6 where species with wide and restricted distributions, respectively, are listed. Mean number of species per quadrat and mean basal cover percent are also given in Table 5.

The mean number of species per quadrat decreased steadily from almost 50 in Group 1 to 36,5 in Group 6. At the same time the standard deviation of the mean increased, indicating that as the mean decreases, the range within a group increases (Table 5). Total basal cover and the cover of the tall and short grass strata are highest in Group 1 and are fairly similar in all the other groups.

All species with a presence greater than 19,9 percent in all groups, and in all groups but one, are listed in Table 5. In particular, *Aristida congesta* and *Themeda triandra* are common throughout the area if a presence of 75 percent is taken as a criterion for within-group abundance. The presence percentages of most of the other species vary from one group to another. Twenty four species have a presence greater than 19,9 percent in all groups and 22 have a presence of less than 20 percent in only one group.

The 38 species with a presence greater than 19,9 percent in four or fewer groups are listed in Table 6. It is noteworthy that only three species, *Eragrostis gummiflua, Euphorbia* sp. and *Fingerhuthia africana,* are restricted to only one group, and all three are found in Group 6 quadrats. Eight species have a presence exceeding 19,9 percent in only two groups. Many species, including *Diheteropogon amplectens, Barleria pretoriensis* and *Eragrostis racemosa,* have a similar pattern of distribution, being found with a high presence percentage in Groups 1 and B. Another group of species, including *Oropetium capense, Sporobolus africanus* and *Hermannia tomentosa,* are found in Groups 4, 5 and 6 although they are not all restricted entirely to these groups.

TABLE 5.—Mean number of species per quadrat, mean basal cover percentage and presence percentage for widely distributed species within each group. X indicates a high cover-abundance rating for the species in most, if not all, quadrats of the groups and a dash (—) a value of less than 20%

Group	1 1	B	3	4	5	6
Mean no. of spp/quadrat	49,5	43,6	46,6	41,0	40,0	36,5
SD of mean	3,4	5,8	8,2	7,1	7,1	7,4
Basal cover: Total %	14,0	10,7	9,0	9,0	10,6	9,9
Tall grass stratum %	6,3	5,0	3,0	3,0	2,8	4,9
Short grass stratum %	7,6	5,7	6,0	6,0	7,8	5,0
SPECIES						
Anthospermum rigidum	100	73	73	88	89	42
Aristida congesta	73X	88	91X	100X	89	100X
Blepharis integrifolia	46	61	73	82	67	42
Commelina africana & C. erecta	55	79	82	71	78	92
Crabbea angustifolia	100	76	82	82	56	42
Diplachne fusca	64	88	82	65	67	42
Elionurus argenteus	91X	88	91X	65X	44	50
Themeda triandra	91X	58	100X	100X	78X	75X
Triraphis andropogonoides	91X	52	91	94	44	67
Anthephora pubescens	82X	21	55	82X	67X	67X
Aristida diffusa var. burkei	91X	73X	55	35	22	42
Barleria macrostegia	82	49	55	59	56	33
Brachiaria serrata	100	91	91	71	44	33
Cassia mimosoides	64	55	64	53	22	42
Dicoma macrocephala	73	21	55	71	56	42
Eragrostis curvula	55	67X	46X	24	44	50X
Eragrostis stapfii	64	24	36	71	56	33
Euphorbia inequilatera	100	36	64	82	78	83
Pogonarthria squarrosa	82	42	64	88	44	33
Raphionacme burkei	36	55	64	47	67	25
Bulbostylis burchellii	55	88	64	24	33	25
Cymbopogon excavatus	46	58X	73X	35	33	33
Ipomoea obscura var. fragilis	55	42	46	41	22	58
Ophrestia oblongifolia	55	73	46	35	22	33
Chascanum pinnatifidum	46	—	27	65	67	50
Corchorus asplenifolius	73	—	73	53	100	50
Cyperus margaritaceus	27	—	46	35	22	58
Eragrostis superba	27	—	36	41	78	75X
Eustachys mutica	46	—	36	65	56	58
Indigofera daleoides	55	—	46	65	78	58
Setaria flabellata	55	—	55	29	33	33
Stipagrostis uniplumis	100X	—	27	71X	78X	100X
Helichrysum cerastioides	46	58	—	53	56	50
Gazania krebsiana	64	36	64	41	—	42
Heteropogon contortus	64X	76	73X	65X	—	75
Pygmaeothamnus zeyheri	46	49	46	24	22	—
Rhynchelytrum repens	27	27	55	24	33	—
Senecio venosus	82	73	46	35	22	—
Solanum supinum	27	24	55	77	44	—
Ursinia nana	55	27	55	71	100	—
Cyphocarpa angustifolia	46	52	55	29	33	—
Acalypha sp. (M & E 1267)*	64	88	55	24	44	—
Chaetacanthus costatus	64	61	36	41	33	—
Helichrysum caespititium	46	88	64	41	67	—
Justicia anagaloides	91	97	100	88	78	—
Kohautia omahekensis	91	30	73	88	89	—

* Specimen housed in National Herbarium, Pretoria.

TABLE 6.—Presence percentage for species with restricted distributions within each group. X indicates a high cover-abundance rating for the species in most, if not all, quadrats of the group and a dash (—) a value of less than 20%

Group	1	B	3	4	5	6
SPECIES						
Eragrostis tricophora	—	—	55X	53X	44	33
Eragrostis lehmanniana	—	—	36	29	67X	67
Vernonia oligocephala	36	—	—	41	33	67
Turbina oblongata	55	—	—	29	44	92
Hermannia tomentosa	73	—	—	53	78	67
Cymbopogon plurinodis	64	—	—	41	33	67
Oxygonum dregeanum	46	64	46	—	22	—
Crassula transvaalensis	73	49	—	29	44	—
Schizachyrium sanguineum	73X	88X	73	24	—	—
Zornea milneana	—	30	55	29	68	—
Andropogon appendiculatus	27	49X	—	—	—	—
Barleria pretoriensis	73	76	—	—	22	25
Chascanum hederaceum	73	79	100	100X	—	—
Dicoma anomala	91	91	73	29	—	—
Diheteropogon amplectens	100X	100X	36	—	—	—
Eragrostis racemosa	64	91	100	—	—	—
Lightfootia denticulata	36	55	—	—	—	—
Polygala rehmannii	46	21	27	—	—	—
Senecio coronatus	27	61	36	—	—	—
Sporobolus pectinatus	46	73	46	—	—	—
Thesium costatum	55	61	—	24	—	25
Trachypogon spicatus	55X	73X	64X	—	—	—
Bulbine sp. (not collected)	—	—	—	35	22	42
Sporobolus africanus	—	—	—	24	33	67
Oropetium capense	27	—	—	24	33	100
Sida chrysantha	—	—	46	24	33	33
Eragrostis gummiflua	—	—	—	—	—	42
Euphorbia sp. (M & B 70)*	—	—	—	—	—	42
Fingerhuthia africana	—	—	—	—	—	58
Cynodon dactylon	—	—	—	—	44	25
Mariscus capensis	—	—	27	—	—	42
Diphlachne biflora	—	52	27	—	—	—
Tephrosia longipes	—	52	46	—	—	—
Setaria nigrirostris	—	—	—	41	22	—
Elephantorrhiza elephantina	—	49	36	—	—	—
Lippia scaberrima	—	—	46	—	22	25
Menodora africana	27	—	—	41	22	—
Nolletia ciliaris	27	—	—	24	—	42

* Specimen housed in National Herbarium, Pretoria.

3.3.3 *Final Groups*

(a) Group 1 (*Diheteropogon-Stipagrostis* Primary Bankenveld)

Two small patches of quadrats of Group 1 (*Diheteropogon-Stipagrostis* Primary Bankenveld) are found north and north-east of Lichtenburg. Other quadrats of this Group occur scattered singly through the north-central and north-western parts of the study area. This small group represents Bankenveld on relatively deep, dolomite-derived soils that have been rested in the recent past or have at least been protected from mismanagement.

Nearly all quadrats are located on the crests of small rises, typical of the area, or on waxing slopes from rises. Two quadrats occur in small hollows. Slope is usually so slight as to be unmeasurable. Chert fragments and loose dolomite rocks are usually found on the ground surface in these quadrats. Soil depth varies from 5 to 10 cm. Soil pH is usually 6,5 and occasionally 7,0. Biotic factors were uniform within the Group. Grazing intensity was light, or moderate, and often the vegetation appeared to have been rested for some time before sampling. Average total basal cover was 14 percent (Table 5), 6,3 percent being contributed by the tall grass stratum (60 to 90 cm tall with many 75 cm tall tufts) and 7,6 percent by the short grass stratum (about 16 cm tall but ranging from 5 to 35 cm tall). Quadrats of this group are rich in species, containing the highest average number of species of any Bankenveld group studied. Species present in over 19,9 percent of the quadrats of Group 1 are given in Tables 5 and 6.

(b) Group 2 (*Diheteropogon-Schizachyrium* Banken veld)

As a whole, Group 2 (*Diheteropogon-Schizachyrium* Bankenveld) appears homogeneous, being retained as an entity from H.S. $\chi^2 = 30,0$ to 13,1. At a level of H.S. $\chi^2 = 8,5$, however, the 33 quadrats of this Group are divided into four groups. Group 2 will be described as a whole and peculiarities of each Final Group will be mentioned. Quadrats of this Group form a belt from east to west across the study area. Group 2b is concentrated in the eastern and central parts of the belt. Group 2a is restricted to three quadrats in the south-western corner and quadrats of Group 2c occur among those of Group 2b. Quadrats of Group 2d are found at the western end of the belt and along the south-central edge of the belt. In comparison with some other groups, whose quadrats are scattered through the study area, this is an easily delimited Group.

Over two thirds of the quadrats of Group 2 occur on crests of rises or on very gentle waxing south- and north-facing slopes. The other third, which are found scattered through all four Final Groups, are in very shallow depressions, on waning slopes to drainage lines, or in small sand-filled sink-holes. Soil is usually 5 to 8 cm deep with chert gravel littered on the soil surface. A solid sheet of dolomite is not found in any quadrat. Soil pH varies between 6,5 and 7,0 and no soil HCl reaction is recorded. With five exceptions all quadrats were lightly grazed or rested and the vegetation was in good condition. Some of the samples were from inside fenced maize lands on soil too shallow for

ploughing. Vegetation in these situations was usually protected from grazing. The exceptional quadrats were heavily grazed and trampled and dolomite was often exposed in them. These quadrats are not excluded from the Group because some, if not all of them, could have been heavily grazed for too few years for their species composition to have altered from this treatment. Average total basal cover in Group 2 was 5,0 percent for the tall grass stratum (usually 75 cm but ranging from 60 to 90 cm in height) and 5,7 percent for the short grass stratum (usually in the range 15 to 30 cm tall). The averages for Group 2b were slightly greater than the overall averages and those for groups 2a, 2c and 2d were equal to, or slightly less than, the averages for Group 2 as a whole. Species present in over 19,9 percent of the quadrats of Group 2 are given in Tables 5 and 6.

On the grounds of the species common to the subgroups and the similar habitat and management features of the quadrats of Group 2 it was decided not to subdivide the Group for description even though it is the largest Group of the analysis. *Diheteropogon-Schizachyrium* Bankenveld is also the most widespread Group in the analysis. It is considered to be the 'normal' or 'typical' Bankenveld of the study area. In distribution, *Diheteropogon-Stipagrostis* Primary Bankenveld (Group 1) forms an extension of this Group and represents a higher successional stage (less disturbance) in the Bankenveld Land System.



FIG. 12.—Featureless Bankenveld Land System scene north of Lichtenburg in *Diheteropogon-Schizachyrium* Bankenveld showing selective grazing. Short grass is mostly *Themeda triandra* and larger tufts are of *Diheteropogon amplectens and Stipagrostis uniplumis*. Trees are mostly *Acacia karroo*. Houthaalbomen, Lichtenburg District.



FIG. 13.—Sand-filled sinkhole partly under cultivation in *Diheteropogon-Schizachyrium* Bankenveld. Trees on horizon are exotics at homesteads. Hendriksdal, Lichtenburg District.

(c) Group 3 (*Chascanum-Eragrostis racemosa* Sandy Bankenveld) and Group 4 (*Chascanum-Anthephora pubescens* Sandy Bankenveld).

These two Groups are discussed together as they are split at the low H.S. χ^2 level of 18,1. The homogeneity of each Group is indicated by neither's being further subdivided until H.S.χ^2 9,5. The combined Group, 3 and 4, is also homogeneous, being maintained as a Group from H.S. χ^2=38,6 to H.S. χ^2=18,1. Thus, as a combined Group and as separate entities, Groups 3 and 4 are relatively homogeneous.

Quadrats belonging to both Groups occur along the western boundary of the area, in a round patch in the north-west, and the few other samples occur scattered through the remainder of the sampled area. Quadrats of both Groups occur together at each locality. Group 4 is the larger of the two and the usual pattern is for a quadrat of Group 3 to occur among a cluster of Group 4 quadrats.

Groups 3 and 4 form a clear ecological nodum associated with a thin, sandy overburden to dolomite. In the majority of quadrats, soil is shallow (5–10 cm), but is occasionally over one metre deep. In most quadrats, the soil surface is free of rock, or contains only scattered, small, chert fragments. It is possible that aeolian sand of Kalahari origin has blown from the west onto the edge of the area, forming a thin veneer over dolomite. Such a movement of sand would be in agreement with the views of Harmse (1967). Within the study area, wind-blown sand has collected in sink-holes and other depressions to form a similar habitat. In Group 4, four quadrats are located in local depressions while a number of quadrats from both Groups occur on flat plains or crests of rises on which sand could easily accumulate. A remarkable feature is, however, that over half the quadrats in Group 3 and over a third of the quadrats in both Groups occur on slightly sloping ground where it would be expected that erosion of sand would be greatest and accumulation least. As the rainfall is relatively low and run-off in the dolomite minimal, sand deposited on a slope is, however, not transported easily. Soil pH is about 6,5 in both Groups. Moderate to moderate-heavy grazing was found in most quadrats of both Groups. When light grazing was recorded, another disturbance factor, like proximity to diamond diggings, was usually noted. Mean number of species per quadrat in Groups 3 and 4 were 46,6 and 41,0, respectively. The tall grass stratum was 60 to 75 cm high in both Groups, with a maximum of 90 cm in Group 3. The short grass stratum was 10 to 30 cm high in Group 3 and 10 to 20 cm high in Group 4. Total basal cover of both Groups was low (Table 5). Species present in over 19,9 percent of the quadrats of Groups 3 and 4 are given in Tables 5 and 6. Many species are common to both Groups and about eight species are found particularly in one or other of the two Groups.

(d) Group 5 (*Corchorus-Ursinia* Bankenveld of Disturbed Sites)

The secondary nature of the vegetation in the quadrats of this Group brought them together on the hierarchy. Some of the quadrats are laid out near diamond diggings, others on abandoned lands and the rest on heavily trampled and overgrazed vegetation. Quadrats of this small Group are scattered through the study area.

Many physiographic combinations are represented. Some quadrats are on crests of rises, some in hollows and some in intermediate positions. North- and south-facing aspects, as well as level sites, are found. Soils are usually shallow, being, in general, from two to eight cm deep and often being gravelly where occurring in fossil river courses. Deeper soil is found occasionally, the deepest for this Group being recorded as 0,5 m. Mean number of species per quadrat was 40,0. Total basal cover averaged 10,6 percent, only 2,8 percent of which was accounted for by the tall grass stratum (usually 60 cm tall but occasionally 90 cm tall). The low total cover and large percentage thereof accounted for by the short grass stratum (15 to 25 cm high) is a further indication of the disturbed nature of the vegetation. Species present in over 19,9 percent of the quadrats of Group 5 are given in Tables 5 and 6.

Group 5 represents areas of disturbed vegetation within the study area. Thus, the areas next to abandoned diamond diggings belong to this Group, even though few quadrats were located there. The influence on the vegetation surrounding the diggings of over 100 000 people (Williams, 1930) who flocked to the diamond fields from 1926 to 1929 must have been great and it is unlikely that the vegetation has fully recovered yet.



FIG. 14.—Graves of diamond miners in typical Bankenveld vegetation with abandoned diamond diggings on ridge in background. Grass in flower is *Themeda triandra*. Bakerville, Lichtenburg District.

(e) Group 6 (*Fingerhuthia-Oropetium* Bankenveld of Dolomite Sheets)

With the exception of three quadrats, which occur scattered through the study area, the quadrats of this Group occur to the immediate north of Lichtenburg, in the southern-most part of the Bankenveld Land System.

Quadrats of this Group occur on extensive plains, in slight hollows and on gentle slopes near crests of plains. Quadrats are found on shallow soils where solid dolomite sheets are exposed on the surface. Soil, if it is present, is usually only 2 to 5 cm deep. Soil pH is usually 7,0 to 7,5, in other words, slightly more alkaline than in most other groups. In three quadrats a slight soil HCl reaction was recorded. Grazing in seven quadrats was light and the vegetation appeared undisturbed. In the other five quadrats of the Group, grazing was moderately-heavy to heavy. Average total basal cover was just under 10 percent, with approximately equal contributions from the tall (usually 75 cm, but ranging from 60 to 120 cm in height) and short (either 10 to 15 cm or 30 to 45 cm tall) grass strata. The mean number of species per quadrat was low (36,5) but the standard deviation of the mean was high (SD = 7,4), indicating that while some quadrats were very poor in species, others were rich. Species present in over 19,9 percent of the quadrats of Group 6 are given in Tables 5 and 6.

The Group is named after *Oropetium capense*, a diminutive grass found in every quadrat of this Group. Gaff (1971) reported that *O. capense* could withstand virtually complete desiccation, a necessary prerequisite for survival on rock sheets with little soil as found in quadrats of this Group.



FIG. 15.—Spoil heaps from abandoned diamond diggings in *Corchorus-Ursinia* Bankenveld of Disturbed Sites. Bakerville, Lichtenburg District.



FIG. 16.—Dolomite outcrop in *Fingerhuthia-Oropetium* Bankenveld of Dolomite sheets. Hendriksdal, Lichtenburg District.

4. DISCUSSION AND CONCLUSIONS

4.1 *Sampling strategy*

It is well documented that strictly systematic and random sampling, although deemed statistically justifiable and even preferable, are inefficient (Taylor, 1969; Werger, 1973). This is chiefly because such strategies result in the inclusion of narrow ecotones in collections of samples, which are then heterogeneous (Grunow, 1965a; Lambert, 1972). It also leads to undersampling generally-recognised but small vegetation units, such as vleis (marshes) and dolerite dyke communities, and over-sampling of large units. Small vegetation units might then not be identified by a statistical method, such as association analysis, which is programmed to terminate at a certain minimum number of samples. Even a group of two or three samples will, of course, be identified by association analysis if its constituent quadrats are sufficiently similar to each other and sufficiently different from other quadrats.

In a vegetation survey such as the present one, more interest is vested in dominant vegetation communities than in narrow ecotones and vegetation units of small area, while areas of intermediate size should be adequately sampled to enable identification and characterisation by the statistical process used. The stratified sampling strategy used for this study ensured that a representative sample of the variation was obtained (see also Werger, 1973), while the random element ensured that the sampling was statistically acceptable. Such a strategy is of particular importance where the number of samples is strictly limited, as it was in this study.

It is preferable to establish optimum sample size in the study area instead of using a size derived elsewhere (Lambert, 1972). In this study, it was considered that compatibility between studies was of greater importance than the derivation of a unique size for this project. Furthermore, results of pilot studies showed that a slightly smaller sample (12 m^2) would have been adequate and 16 m^2 was considered large enough to be a 'safe' minimum size for the entire Highveld Ecological Survey (J. C. Scheepers: pers. comm.).

Extensive cultivation in the CT Grassland Land System made sampling difficult. Not only are clusters of samples situated far apart, but great difficulty was experienced in getting samples representative of all vegetation types which were presumed to have existed in the area previously. Some types have almost certainly disappeared completely. As it is vegetation on soils that are less suitable for cultivation which remains, a marked sampling bias towards vegetation on these soils and away from that on soil suitable for cultivation is likely to have taken place.

The number of samples in both Land Systems is small. In CT Grassland there was the physical problem of fitting samples into a restricted area of natural vegetation while in Bankenveld it was considered that the major vegetation types had been adequately sampled by 110 samples. The limited period for fieldwork during the present study also affected the number of samples which could be taken.

There were two reasons for the small number of habitat variables recorded at each site. Firstly, as the study was conceived as a semi-detailed survey of short duration, intensive study of ecological interrelationships was not planned. Secondly, the number of habitat factors which can be studied in Bankenveld is limited by the nature of the soil. In many places, sheets of dolomite are exposed at the surface and the plants are rooted between rocks. Measurement of field capacity, wilting point, and similar measures are difficult as a result.

4.2 *Methodological aspects*

The broad differences between Bankenveld and CT Grassland Land Systems, outlined in section 1.7, are shown to be supported by quantitative analysis of the vegetation. The Total association analysis separated most quadrats laid out in Bankenveld from those laid out in CT Grassland. Nineteen Bankenveld quadrats occurred in groups consisting mainly of CT Grassland quadrats but Bankenveld groups never included CT Grassland quadrats. It was therefore concluded that certain Bankenveld vegetation quadrats resembled vegetation of CT Grassland groups in their floristic composition, but that no CT Grassland samples resembled Bankenveld groups. Of Bankenveld quadrats classified with CT Grassland groups, 42 percent were from Group 7 of the Bankenveld hierarchy and 37 percent were from Group 6 of the same classification. Group 7, the last group of the Bankenveld classification, was found to be a heterogeneous group of quadrats. The species composition of many Group 7 quadrats could be such that, by chance, they did not contain the dividing species necessary to include them in a group in which they would have been appropriate. In the Total analysis also, these quadrats were shown to be a heterogeneous collection by their being scattered through a number of final groups.

Apart from strong, positive species associations within quadrats of each Land System and negative associations between them, floristic richness may be partly responsible for the major automatic division between Bankenveld and CT Grassland. A floristically-rich group of quadrats is defined as one with a relatively high mean number of species within each quadrat of the group and a floristically-poor group is the converse. That floristic richness of quadrats may influence the nature of the resulting hierarchy was noticed on inspection of the mean numbers of species per quadrat in each final group of both hierarchies. In the Bankenveld classification, the mean decreases steadily from Group 1 (49,5) and Group 2 (43,6) to Groups 6 (36,5) and 7 (32,9), across the hierarchy from left to right. Thus, floristically-rich groups split off first and floristically-poor quadrats generally remain until last. Although evidence is not available, it is conceivable that more positive species associations are present in floristically-rich collections of quadrats, making the collections more homogeneous and therefore more likely to be split off. A similar decrease from left to right in mean number of species per quadrat was found in the Total analysis. The overall mean number of species per quadrat is, however, much lower. The overall average in the 110 Bankenveld quadrats exceeds 40. In CT Grassland Groups 4b, 5b, 6 and 7a, which contain most species per quadrat, the mean is less than 27. The average decreases steadily to the last Group, 9c, with a mean of 15,2. Thus, if floristic richness is a factor controlling the results of the classification, the marked division between Bankenveld and CT Grassland Land Systems would be expected. It is also the possible explanation for floristically-poor Bankenveld quadrats of Groups 6 and 7 occurring with floristically-poor CT Grassland groups in the Total analysis.

To obtain the greatest amount of information from the association analyses they had to be interpreted at more than one stopping level. A single stopping rule, as initially proposed by Williams & Lambert (1959, 1960), was not adequate. It is considered, furthermore, that experience with use of the method greatly improves the result that is obtained. Association analysis should be considered as an aid in the study of vegetation and not as a tool to be applied by technicians with no training in its use and misuse.

Although a few quadrats could not be successfully re-allocated, the use of species recorded around the edge of the quadrat to re-allocate quadrats was successful. Had total floristic composition also been taken into account in the re-allocation procedure and not only habitat features and species in the surrounds of quadrats, an even more successful re-allocation may have been realized.

Indicator values were of use for determining significance levels for species occurring more commonly inside a group than outside it. Used in conjunction with positive and negative dividing species and cover-abundance estimates, Indicator values enabled good floristic definitions of groups to be made. On the other hand, negative Indicator values, given to species occurring more frequently outside a group than inside it, were of limited use (see Morris, 1973).

Although no objective criteria for measuring success are known, it may be concluded that the technique of association analysis performed adequately in providing a generally interpretable classification of the vegetation. A perfect classification of a data set of this size probably does not exist and the utility of a particular strategy as an aid for the study of the vegetation should be the criterion on which the classification is judged.

4.3 *Vegetational aspects*

In the Total association analysis, division between Bankenveld and CT Grassland quadrats is fairly clear. As the Bankenveld area was considered most important from a vegetational point of view and as there was some mixture of Bankenveld quadrats in groups of predominantly CT Grassland quadrats, a separate analysis of the 110 Bankenveld Land System quadrats was undertaken. It was not considered profitable to interpret Bankenveld final groups in both the Total analysis and the Bankenveld analysis. In a general way, results of the Bankenveld analysis and Bankenveld part of the Total analysis are similar.

In CT Grassland, eleven final groups are recognised and described. Two final groups, Short and Tall *Stipagrostis uniplumis* Calcareous Grassland, occur on soils overlying surface limestone deposits with the same geomorphology and soil series. Soils are generally slightly deeper and basal cover of tall grasses is double in quadrats classified as Tall Grassland in comparison with quadrats of Short Grassland. In both Groups grazing is usually light. The community is found around Lichtenburg and in a belt extending west of the town.

Another two final groups, *Elionurus argenteus* Secondary Grassland and *E. argenteus* Primary Grassland, occur on rocks of the Ventersdorp system. Heavy grazing and soil erosion are often recorded from quadrats of the former while the vegetation is usually in good condition in the latter Group. Most *Elionurus argenteus* Grassland is found south-west of Lichtenburg.

Two final groups also occur on Dwyka tillite substrate. They are *Cymbopogon plurinodis* Grassland and Secondary *Cymbopogon plurinodis* Grassland. The difference between these two Groups is also in degree of biotic influence but, as there are only three quadrats in the latter Group, the distinction does not carry much weight.

Three final groups, *Acacia karroo* Savanna, *Acacia karroo* Open Woodland and Drainage Basin *Acacia karroo* Open Woodland are found on the medium- and poorly-drained soils of the area. Heavy grazing and trampling are usual in quadrats of these Groups. Most quadrats are situated on Ventersdorp Series rocks. In all three Groups a woody element is present with *Acacia karroo* as the dominant tree and shrub species.

It is concluded from the description given that the major vegetational differences in the CT Grassland Land System can be related to the geological substrate and gross soil characteristics. Within major groups, management is often an important factor although, in some cases, there are not enough quadrats in a group for even a reasonable degree of certainty. Two final groups, one of only three quadrats, from adjacent legs of the hierarchy could not be interpreted.

In the Bankenveld association analysis ten final groups are distinguished. For discussion, the four final groups of Group 2 are lumped and Groups 3 and 4 are also lumped. Suggested relationships between Bankenveld groups are indicated in Fig. 17.

It is considered that Group 2 (*Diheteropogon-Schizachyrium* Bankenveld) is the typical vegetation of the Bankenveld Land System. Group 1 (*Diheteropogon-Stipagrostis* Primary Bankenveld) consists of quadrats laid out in vegetation that had been well managed. Group 1 is closely related to Group 2 but has experienced less selective or heavy grazing and trampling in the past. It may be considered as the 'climax' vegetation type, although it possibly occurs in a slightly different habitat.

Quadrats of Groups 3 and 4 (*Chascanum-Eragrostis racemosa* Sandy Bankenveld and *Chascanum-Anthephora pubescens* Sandy Bankenveld) occur together on the western edge of the Bankenveld Land System and in a circular patch in the north-west of the study area. Differences between the two Groups are not clear. Both are found where sand overlies dolomite. It is suggested that aeolian sand has been blown from the west over the dolomite and provided the habitat for these Groups.

Past disturbance in the area was discussed earlier. It is suggested that quadrats of Group 5 (*Corchorus-Ursinia* Bankenveld of Disturbed Sites) are those in vegetation which has been disturbed in the past.

Exposed sheets of dolomite are characteristic of parts of Bankenveld, particularly in the area to the immediate north of Lichtenburg. Group 6 (*Fingerhuthia-Oropetium* Bankenveld of Dolomite Sheets) is the vegetation typical of such areas.

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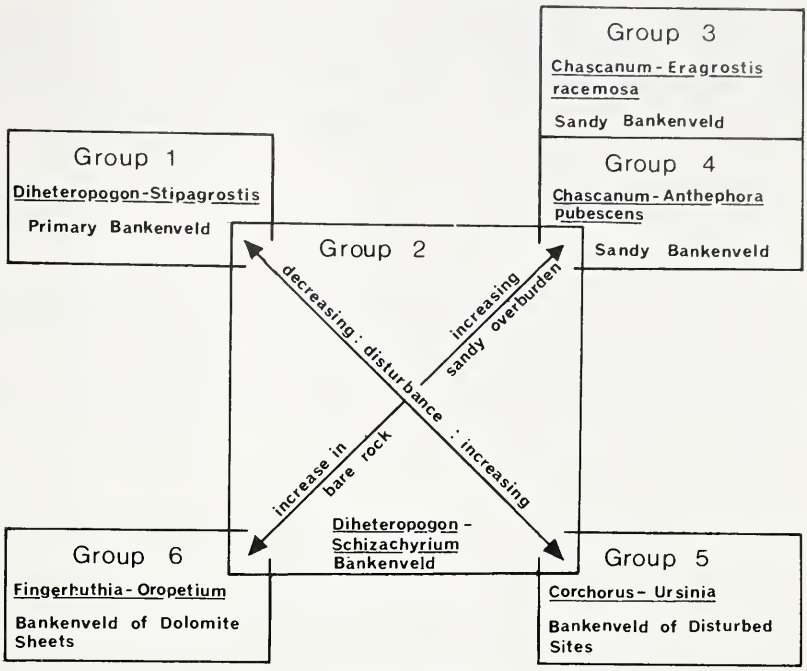


FIG. 17.—Suggested relationships between Bankenveld association analysis groups.

UITTREKSEL

'n Kwantitatiewe, semi-gedetaileerde plantekologiese-studie is gedoen vir die gebied tussen 25°54′ *en* 26°22′ 0 *en* 26°00′ *en* 26°20′ *S, geleë rondom Lichtenburg in suidwes-Transvaal. Die gemiddelde jaarlikse temperatuur van hierdie studiegebied is* 17°*C en die jaarlikse reenval is omtrent* 600 *mm. 'n Basiese verskil kan waargeneem word tussen die Bankenveld Land Sisteem en die CT Grasveld Land Sisteem. Eersgenoemde het 'n onderlaag van dolomiet met litosoliese grond, Bankenveld plantegroei en veeboerdery as vernaamste bodembenutting. In teenstelling daarmee het laasgenoemde 'n onderlaag van graniet, Ventersdorp lavas, Dwyka kleileem (tillite) en oppervlakkalksteen met Shorrocks, Mangano en Lichtenburg grondseries,* Cymbopogon-Themeda *Veld plantegroei en ekstensiewe mielieboerdery as hoof bodembenutting. Een honderd en tien* 16 *m² kwadrate is geplaas in elke land sisteem deur middel van gestratifiseerde ewekansige monstering. Van die* 247 *spesies wat teegekom is, het amper 'n honderd in minder as* 6 *kwadrate voorgekom.* Themeda triandra, Aristida congesta, Elionurus argenteus, Anthospermum rigidum *en* Justicia anagaloides *het deurgaans baie algemeen voorgekom. Twee assosiasie-analises is gedoen en* 15 *finale groepe is geïnterpreteer vanuit 'n totaal van* 21 *groepe.*

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Cape Hangklip area. I. The application of association-analysis, homogeneity functions and Braun-Blanquet techniques in the description of south-western Cape vegetation

C. BOUCHER*

ABSTRACT

Relevé data were collected in two phases from, respectively 150 and 100 sampling points distributed by stratified random means through almost 24 000 ha of vegetation. Association-analysis, Braun-Blanquet and homogeneity function methods were used to treat the data. Only the "normal" association-analysis method was applied. Three sorting techniques for tabulating the data were tested and were compared with a fourth method. Homogeneity functions were used to construct a dendrogram and to determine the degree of similarity between individual relevés and groups of relevés. After comparison of the methods, it was concluded that the Braun-Blanquet method is consistently more efficient and more exact, even in the floristically rich vegetation of the south-western Cape Province of South Africa.

RESUME

REGION DU CAP HANGKLIP. I. L'APPLICATION DE L'ANALYSE D'ASSOCIATION, DES FONCTIONS D'HOMOGENEITE ET DES TECHNIQUES DE BRAUN-BLANQUET A LA DESCRIPTION DE LA VEGETATION DU SUD-OUEST DE LA PROVINCE DU CAP

Les données des relevés ont été rassemblées en deux phases à partir de 150, *puis de* 100 *points de récolte distribués par stratification aléatoire sur près de* 24 000 *ha de végétation. Le traitement de ces données a été effectué suivant les méthodes d'analyse d'association, de Braun-Blanquet et de fonctions d'homogénéité. Seule la méthode d'analyse d'association "normale" a été employée. Trois techniques de triage pour la confection de tables de données ont été testées et comparées à une quatrième méthode. Les fonctions d'homogénéité ont été employées pour construire un dendrogramme et déterminer le degré de similitude entre les relevés individuels et les groupes de relevés. Après comparaison des méthodes, on a conclu que la méthode de Braun-Blanquet est plus efficiente et plus exacte, et ceci d'une façon consistante, même dans la végétation floristiquement riche du sud-ouest de la Province du Cap en Afrique du Sud.*

INTRODUCTION

Little descriptive work has been done on the vegetation of the south-western Cape Province of South Africa. Acocks (1953) has remarked that the Cape Fynbos vegetation "is a complex vegetation, and to divide it simply into Macchia and False Macchia is like dividing the tropical vegetation into grassveld and bushveld"

Statistical approaches have been used by Rycroft (1951), Grobler (1964), Taylor (1969) and Hall (1970) as aids in the description of this vegetation. The largest area of vegetation described and mapped in detail is the 7 680 ha of the Cape of Good Hope Nature Reserve (Taylor, 1969). This latter study was the first attempt at applying association-analysis (Williams & Lambert, 1959, 1960, 1961; Lambert and Williams, 1962) and Zürich-Montpellier methods (Braun-Blanquet, 1932; Becking, 1957; Küchler, 1967) to the Fynbos element (Taylor, 1972) of the South Western Cape vegetation. The Zürich-Montpellier principles, expressed by Braun-Blanquet and further developed theoretically by many followers (Werger, 1973b), will here be termed the Braun-Blanquet method. The Braun-Blanquet method has subsequently been used to describe some 373 ha of Fynbos vegetation in the Jonkershoek State Forest near Stellenbosch (Werger, Kruger & Taylor, 1972).

A method was required in the south-western Cape that would be most suitable for the evaluation, description and classification of large tracts of Fynbos vegetation. The Cape Hangklip area was floristically rich and included many variations of habitat. It would, therefore, be an exacting test of the suitability of any method. This served as the stimulus to apply homogeneity functions (Hall, 1967a & b, 1969a, b & c and 1970), association-analysis and Braun-Blanquet techniques.

The study area consists of about 24 000 ha of coast and mountain vegetation. The boundaries were taken as those of the 1:50 000 Topographical Survey Sheet 3418BD Hangklip (Trigonometrical Survey, 1968) and the portions of the Kogelberg State Forest which occur outside this sheet.

METHODS

The sampling method

Relevé data were obtained from 150 and 100 sites scattered respectively over 11 506 and 12 354 ha. Sites were distributed randomly within physiographic-physiognomic units delimited on aerial photographs. In the first phase of 150 relevés, each of the 10×5 m relevés were strictly laid out with the longest axis on a north-south magnetic bearing. In the second phase each of the 100 relevés was so positioned that a maximally homogenous sample was recorded.

For comparative purposes, only permanently recognizable species were listed, others being listed merely for record purposes. An additional list of species, occurring in the surrounds of the relevé within the community being sampled, was also made.

Listed species were given cover-abundance and sociability values (Becking, 1957). A modified scale of abundance, similar to that described by Hanson (Brown, 1954), was used to assist in describing each community.

As required by association-analysis and homogeneity functions, a standard relevé size of 10×5 m was used throughout. This size is identical to that used by Taylor (1969) for conformity in the event of comparisons being made. Comparisons of sample size versus

* Botanical Research Unit, P.O. Box 471, Stellenbosch.

information recorded are made in Table 1. The data used in these comparisons were obtained from visibly different communities.

TABLE 1.—Average species-area curve comparisons (from Boucher, 1972)

Relevé area	Species content as a % of the maximum	Reduction in area as a % of the maximum
120m²	100%	0%
110m²	97%	9%
100m²	94%	17%
90m²	91%	25%
80m²	88%	33%
70m²	85%	42%
60m²	82%	50%
50m²	79%	58%
40m²	75%	66%
30m²	71%	75%
20m²	64%	83%
10m²	54%	92%

The following additional information was recorded at each sampling site: soil type, soil moisture, degree and type of stoniness, local climatic data, geology, geomorphology, species dominance, species height, vegetation age, disturbances, etc.

The association-analysis method

The various forms of association-analysis, namely, "normal", "inverse" and "nodal" analyses, have been fully described by the developers of the method and by numerous other workers. South African workers who have applied this method include Van der Walt (1962), Grunow (1965), Downing (1966), Roberts (1966), Woods & Moll (1967), Miller & Booysen (1968), Scheepers (1969) and Taylor (1969).

Scheepers (1969) found that the inverse analysis produced a stepwise arrangement of species grouping (also known as "chaining") which was difficult to interpret. Morris (pers. comm.) considered this stepwise arrangement to be a fairly regular feature of the method when large numbers of species were involved, as in this case. It was considered advisable to restrict treatment of the data to the normal type of analysis. Information gained from inverse and nodal analyses would, in most instances, not warrant the extra expenditure in computer time. A programme for the nodal analysis was not locally available at the time.

The subdivision parameter used was the highest $\Sigma\sqrt{\frac{x^2}{N}}$ value which Williams and Lambert (1959, 1960) considered to result in the most efficient subdivision, although the optional facilities of $\Sigma\, x^2$ or $\Sigma\frac{x^2}{N}$ were available. Termination of subdivision took place when there were less than eight relevés left in the group or when the highest single x^2 equalled 3,841 or less.

The Braun-Blanquet method

The Braun-Blanquet method, commonly used in Europe and elsewhere, has been little used in South Africa. The only English source of information on this method was Fuller and Conard's (Braun-Blanquet, 1932) authorized translation of Braun-Blanquet's first edition of Pflanzensoziologie (Braun-Blanquet, 1928). More recent English descriptions of the method were published by Poore (1955), Becking (1957) and Küchler (1967), amongst others.

Taylor (1969) was the first to use the method in South Africa. He prepared a synthesis table from data collected in systematically distributed relevés and obtained associations which were recognizable in the field. Werger, Kruger & Taylor (1972) then applied the phytosociological technique as further described by Ellenberg (1956) and Braun-Blanquet (1964), to test its usefulness in the floristically rich Fynbos vegetation in a portion of the Jonkershoek State Forest. A practical classification into communities based on floristic criteria was obtained. This method has subsequently been used by, amongst others, Coetzee (1972) in the Jack Scott Nature Reserve, by Werger (1973a & b) in the Upper Orange River Valley, and by Musil, Grunow & Bornman (1973) on aquatic vegetation in the Pongola Pans, Zululand.

Aids have recently been developed to assist in sorting tabulated data. Müller *et al.* (1972) designed a mechanical sorting apparatus for ordering data by shifting aluminium strips on which the information is symbolized by coloured rivets. A computer programme, TABSORT, developed by the Department of Forestry at Jonkershoek near Stellenbosch, allows the data matrix to be manipulated simply by listing the relevé and species sequences in the required new order. Ceska and Roemer (1971) have developed a computer programme that identifies species-relevé groups in vegetation, thereby removing the much disputed personal bias from table-work.

Method using homogeneity functions

Homogeneity functions for identifying groups in a matrix of vegetation d ta have been developed by Hall (1967a & b, 1969a, b & c and 1970). A function, given as H_{qm}, is written, for the subset of $t=1 \ldots k$ sample plots and all the $j=1 \ldots p$ species, as follows:

$$H_{qm}=\sum_{j=1}^{p}\frac{\sum_{t=1}^{k} a_{jt}}{\sum_{j=1}^{p}\sum_{t=1}^{k} a_{jt}}\left(1-\frac{s_{ajk}}{s_{hjk}}\right)$$

where s_{ajk} and s_{hjk} are the standard deviations of the subset's actual data row for the jth species, and a dummy maximally heterogeneous row, respectively; a_{jt} is the value for the jth species in sample plot t. These methods have only been tested on small vegetation data matrices from the Bains Kloof area of the Cape Province. A simplified form of this homogeneity function determines the similarity between the average members of each major group, subgroup, sibling-group (Hall, 1969a) or core and each relevé, thereby indicating the "goodness of fit" of each relevé in each vegetation group delimited.

The similarity between two items or average members t and k can be given by this simplified version of the homogencity function. By similar notation,

$$H_{qm}=\sum_{j=1}^{p} M_j(1-|a'_{jt}-a'_{jk}|)$$

Here, the modulating factor M_j is calculated exactly as before. The homogeneity expression that follows, uses abundance values scaled to a range with a maximum of one, a'_{jt} and a'_{jk}. The scaling of the jth species is based on its largest operational value (Hall, 1970).

RESULTS AND DISCUSSION

Association-analysis

For practical reasons collection and treatment of the data were divided into two separate phases.

ASSOCIATION-ANALYSIS HIERARCHY

FIRST PHASE

281 species
150 plots

Chondropetalum hookerianum (+92 / −58)

Anthospermum ciliare (+18 / −74)

Erica hispidula (+38 / −36)

Erica fastigiata (+15 / −23)

Restio egregius (+13 / −5)

Leucadendron xanthoconus (+2)

Lanaria lanata (+9 / −11 / −2)

Sympieza paliescens (+4 / −11)

Drosera glabripes (+6)

Proteo cynaroides (−5)

Erico placentaeflora (+7 / −16)

Tetroria fasciata (+11 / −5)

Osmitopsis parvifolia (+4 / −7)

Blaeria dumosa (+6)

Indigofera mauretanica (+1 / −30)

Dilatris pillansia (−29 / +4 / −25)

Staberoha cernua (+12 / −13)

Chandropetalum deustum (+7 / −6)

Hypolaena digitata (+6 / −6)

Hypodiscus aristatus (+8 / −50)

Metalasia muricata (+24 / −26)

Rhoenocarpo prolifero (+4 / −4)

Erico carifolia (+1 / −3)

Aspalathus farbesi Struthiola ciliata subs. schlechteri (+4 / −20)

Passerina paleacea (+10 / −10)

Aspalathus biflora (+1 / −9)

Erica pulchella (+4 / −22)

Montinia caryophyllacea (+5 / −17)

Osmitopsis parvifolia (+2 / −15)

Leucadendron xanthoconus (+4 / −11)

Erica Restio intervallaris purpurascens (+4 / −7)

Merxmuellera cincta (+5 / −2)

GROUP NO.	PLOT NO'S.
1	27 \| 62
2	11 \| 48 / 55 \| 59 / 61 \| 64 / 65 \| 66 / 68
3	4 \| 57
4	49 \| 69 / 70 \| 86 / 134
5	60 \| 75 / 131 \| 132
6	137 \| 145 / 146 \| 147 / 149 \| 129
7	84 \| 142 / 143 \| 144 / 150
8	10 \| 20 / 22 \| 46 / 47 \| 71 / 72
9	74 \| 77 / 108 \| 133
10	9 \| 12 / 54 \| 63 / 76 \| 82 / 139
11	98 \| 103 / 120 \| 123 / 140
12	73 \| 87 / 88 \| 90 / 104 \| 106
13	119
14	97 \| 99 / 105 \| 122
15	92 \| 96 / 107 \| 115 / 118 \| 127
16	111 \| 113 / 116 \| 124 / 125 \| 126
17	78 \| 79 / 80 \| 81 / 85 \| 93 / 138
18	94 \| 95 / 109 \| 110 / 114 \| 141
19	5 \| 6 / 23 \| 26
20	121
21	50 \| 51 / 53
22	28 \| 30 / 31 \| 43
23	29
24	2 \| 32 / 33 \| 34 / 35 \| 36 / 37 \| 44 / 45
25	8 \| 15 / 16 \| 21 / 24 \| 25 / 38 \| 39 / 41 \| 58
26	7 \| 42 / 67 \| 102
7	13 \| 89 / 91 \| 100 / 101
8	52 \| 148
9	128 \| 130 / 135 \| 136
30	56 \| 83 / 112 \| 117
31	14 \| 17 / 18 \| 19 / 40
3	1 \| 3

Subdivision level (highest single χ^2 - logarithmic scale)

120 110 100 90 80 70 60 50 45 40 35 30 25 20 15 10 9 8 7 6 5 4 3,84

3,84 level

Linear representation of hierarchy

LEGEND

+ or − Indicates presence or absence of dividing species.

no. e.g.17 Indicates number of sample plots in subdivision.

FIG. 1.—First-phase association-analysis hierarchy from Boucher (1972).

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TABLE

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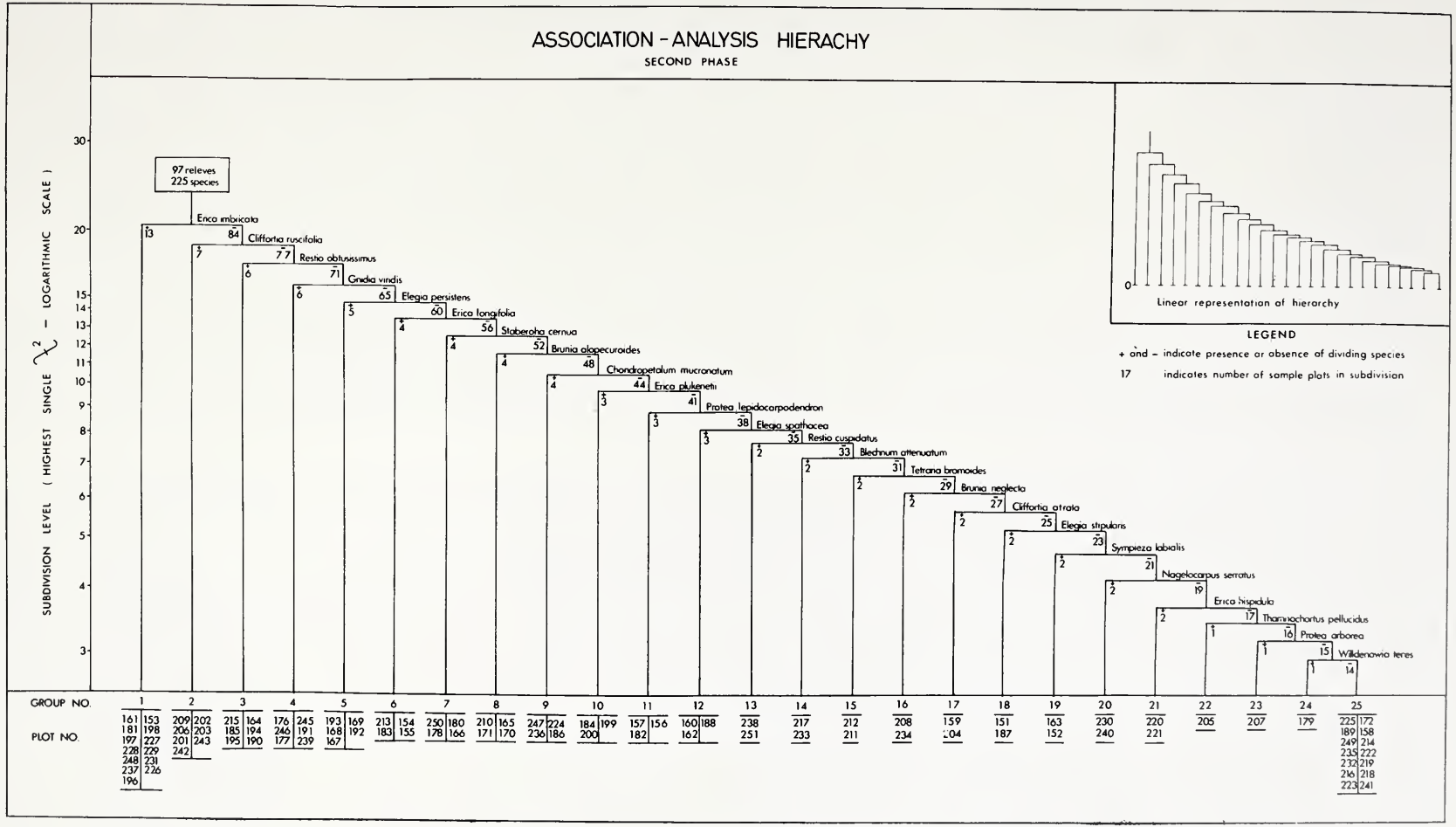


FIG. 2.—Second-phase association-analysis hierarchy.

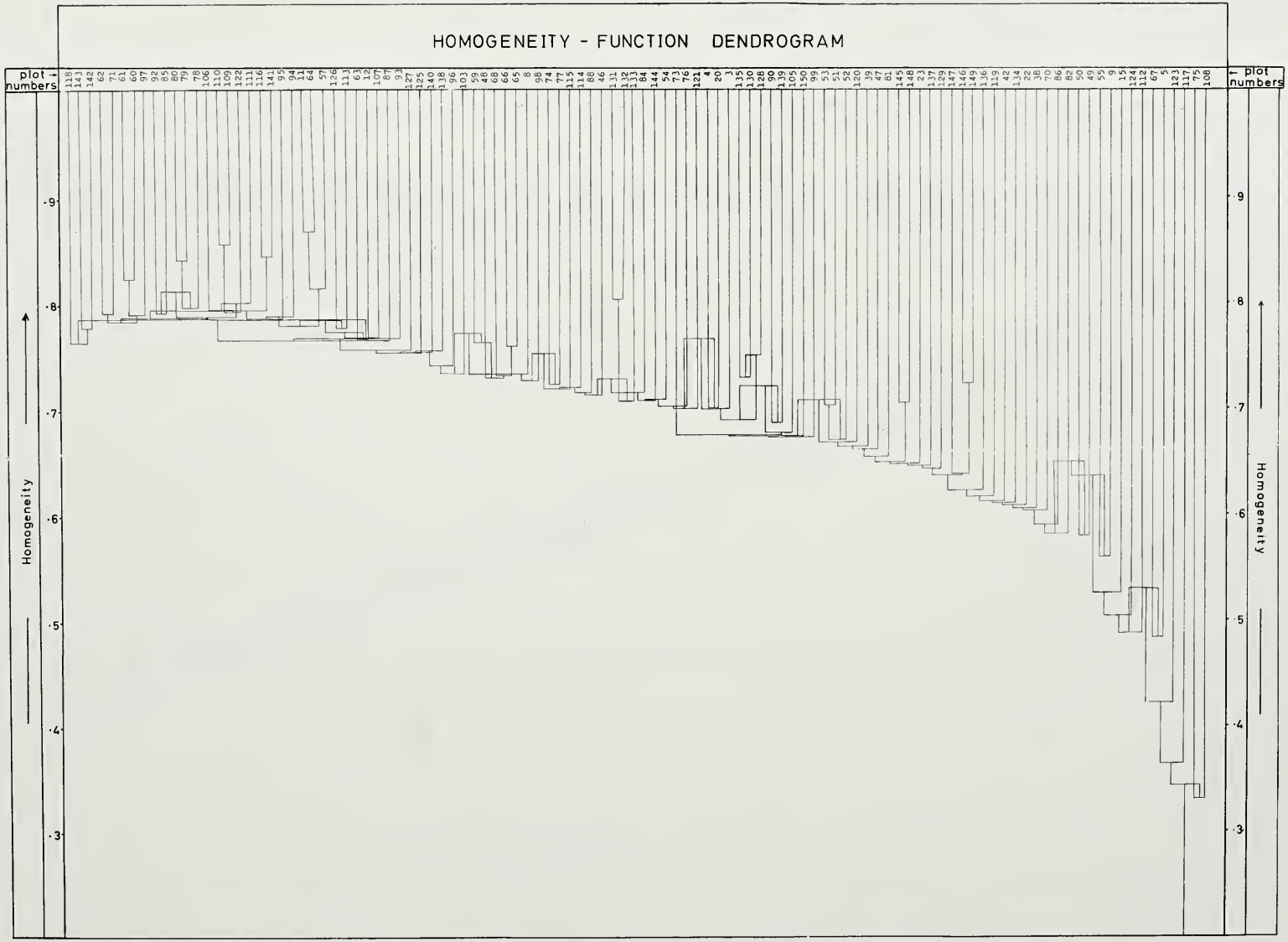


FIG. 3.—Homogeneity-function dendrogram from Boucher (1972).

In the first phase, 150 relevés were ordered into 32 final groups in the association-analysis hierarchy (Fig. 1). The hierarchy was constructed following the the conventional procedure of listing positively defined relevés, at each subdivision, on the left-hand limbs and the negatively defined relevés on the right-hand limbs. To present the information in a more practical fashion, a logarithmic, instead of a linear scale, was used for values of highest single x^2. The linear representations are inset in Figs 1 and 2.

The hierarchy showed relatively uniform divisions with little tendency to chaining, except in the final negatively associated portion, where the more distinctive communities such as the coastal dune vegetation and wet seepage communities, occurred. A reversal, or increase, in level of subdivision of a subsequent group, following the removal of a more homogeneous group, occurred after group 12 had been delimited. In certain instances, such as in the subdivision of groups six and seven, two species could equally well have been used to effect the subdivision, both resulting in the smallest total of residual significant associations in the two resulting subclasses. When such an ambiguity occurred, the computer was instructed to subdivide on the species with the lowest coding number.

In most cases communities proved to be undersampled rather than oversampled. In very few instances would the recombination of adjacent final groups have resulted in ecologically valid larger groups.

A major difficulty, probably more commonly found in monothetic divisive techniques was the occurrence of apparent misclassifications. These were found especially during the first major subdivisions when large numbers of relevés were involved. Here the chance absence of a species within a particular relevé, although it occurred within the community being sampled, could result in the misclassification of the relevé. This contingency was largely overcome by listing species not found inside the relevé but occurring in its immediate vicinity, within the same community. The reclassification of any relevé could be undertaken on these grounds. In a number of instances the cause was found to be the misidentification of the dividing species. This was attributed to the drought conditions prevailing at the time and to the problem of identifying vegetative specimens. The collection of 114 species of Ericaceae, characterized by ericoid leaves, underlines the reality of this problem. More than 1 400 different species were collected during this survey.

Eleven relevés were regrouped after the relevant dividing species were found in the surround lists, while five were found to be wrongly grouped because of misidentifications. Two were transitional. The final groups in the hierarchy were found to vary in the degree of their floristic and ecological homogeneity. Insufficient sampling could be a possible reason.

The description and mapping of the vegetation of a portion of the study area was based on these final groups because they showed highest correlation of communities with habitat. A hierarchical arrangement has the advantage of providing a dichotomous key for the identification of communities.

In the second phase of the study, 97 of the 100 relevés were divided into 25 final groups (Fig. 2). (Data from 3 additional relevés were collected at a later stage to strengthen some of the Braun-Blanquet groups.) In contrast to the previous and most other normal analysis hierarchies, a total chaining of groups occurred. There was virtually no correlation of groups with habitat factors, but groups 1, 2 and 4 showed some correlation with Braun-Blanquet groups. The remaining groups did not appear to be correlated floristically or with habitat factors and were, therefore, not used in the description of the vegetation.

Braun-Blanquet

The conventional technique of manually rewriting the table while sorting the data was used initially. (No other facilities were then available.) A few major groups were distinguished which were further compared using homogeneity functions. Further refining of the data was attempted once the TABSORT programme became available. A few more communities were extracted and the complex interrelationships between the communities were better shown (Boucher, Part II, in preparation).

The Ceskar & Roemer programme for identifying species-relevé groups was tested on the same data. The criteria applied for grouping were 50% and 66% species occurrence within a group, each species having a maximum of either 10% or 20% occurrence outside that group. The groups delimited conformed to the major groups that were readily identifiable using conventional sorting methods. Considerable further refinement of the table using another method would therefore appear to be necessary after using this programme. This suggests that it could be a useful tool only for the initial sorting of the data.

In the second phase, where the collection of relevé data conformed more to the principles laid down by Braun-Blanquet, the data could be refined to a fairly detailed level with the aid of the TABSORT programme (Boucher, Part II, in preparation). The subjective location of sampling sites resulted in their most efficient distribution within the many variations occurring in the vegetation. An understanding of the vegetation, gained during the first phase, resulted in fewer transitional areas being sampled. The Braun-Blanquet groups obtained in the second phase were therefore clearer than those obtained in the first phase.

The TABSORT programme was used to study the meaning of the association-analysis groups in terms of the Braun-Blanquet community concept. The species rows were rearranged to determine whether any pattern of distribution would support the association-analysis groups. Relevés were also rearranged within each of these groups but not between the groups. On the basis of Braun-Blanquet differential species, some of the association-analysis groups were heterogeneous. This is possible when the grouping is based on total species complement in each relevé. A relationship of a different type, such as fire-age, might be indicated. This detracts from the acceptance of the association-analysis, in comparison to the Braun-Blanquet, groups for community classification.

Homogeneity functions

The initial subdivision of the data before applying homogeneity functions was done using the Braun-Blanquet method. The easily extractable, obvious groups were accepted prior to being further analysed using homogeneity functions. The residual data matrix consisted of 108 relevés having 185 permanently recognizable species occurring in more than two relevés. This matrix was still too large for analysis by this method with the available computer facilities. It was, therefore, further reduced by excluding the species of less frequent occurrence until 86 species remained.

A chaining effect was obtained in the homogeneity function dendrogram (Fig. 3) with virtually no distinct clustering. A broad moisture gradient could be discerned in the arrangement with drier sites linking onto the matrix at the higher homogeneity

levels and wetter sites linking at the lower homogeneity levels. This was similar to the association-analysis grouping where the wet seepage communities linked at the lower highest single χ^2 values.

The data matrix for comparison using the homogeneity functions consisted of the less distinct communities. The absence of the species of rarer occurrence probably reduced the sensitivity of the method to an excessive degree. The end product was, therefore, unsuitable for the description or the mapping of the vegetation.

The distinctness of the recognized groups, and of the members in each group, to their average member was determined using the simplified form of the homogeneity function. With this method a member, when compared to itself, would be 100% similar. All the groups recognized were compared to each other, whether they were those delimited by the Braun-Blanquet method or were indistinct groups or arbitrary cores extracted from the homogeneity function dendrogram. The distinctness of the Braun-Blanquet groups was confirmed (*vide* the example in Fig. 4, where the length of the bar indicates the degree of similarity). The degree of similarity between the relevés in the complex data matrix was also readily shown diagrammatically by the length of the bars.

Affinities between groups and the best location of transitionary relevés are easily shown by this method.

CONCLUSIONS

The relevé size (10 m × 5 m) was found to result in an adequate sample of each community, at the scale of study involved. The relevé shape could possibly have been more flexible, for instance in sampling the riparian communities which form narrow bands along streams. The less rigid sampling arrangement of the second phase, where the relevé was not placed in a fixed direction, but in a position to ensure maximum homogeneity, resulted in fewer transitions being sampled and thereby proved to be more satisfactory.

Although the mechanical table sorter was not used to re-arrange the data during this study, experience in its use indicates that it has certain advantages and disadvantages over the TABSORT programme. It is quicker to compare relevés with one other and with developing groups with the mechanical table sorter, because direct comparisons are possible. This is most easily simulated with the TABSORT programme by strip-cutting the data, although this can be tedious and liable to error. Copies of new arrangements must frequently be made. The TABSORT programme has the advantage of providing an immediate neatly typed copy of the table of any required stage. This could be useful for comparison between stages of refinement, particularly for teaching purposes. The mechanical table sorting method is more liable to human transcript errors. The size of the data matrix (150 × 363) was not limited by the computer capacity during this study but rather by the number of relevés and species which could be efficiently dealt with in the actual arranging. The mechanical sorter data matrix size is limited by practical design and ease of handling (124 × 130 in the prototype).

Taylor found that association-analysis revealed groups which were ecologically meaningful, but that most of the groups represented . . . " such small isolated fragments of natural units that they do not give a harmonious picture of the vegetation" (Taylor, 1969). In the first phase of the Hangklip survey, the ecologically meaningful groups required little subjective ordering to form a more harmonious picture of natural units. The groups in the second phase were found, in contrast, to represent isolated fragments which would require considerable subjective rearrangement. This was in agreement with Taylor's findings. The latter result was unexpected, because care had been taken to ensure the most efficient sampling.

The Braun-Blanquet method was found to be more consistent, primarily because the communities are better defined in that they do not depend on single species presence or absence for final group forming. In addition the relationship between the communities is readily demonstrated. Donselaar who used the Braun-Blanquet method in the savannas of Northern Surinam is mentioned by Werger *et al.* (1972) as stating that the number of species must be moderate for this method to be successful. The latter workers, in contrast, found the method to be practical in floristically rich fynbos vegetation. During the present study more than 1 400 different species were collected. In the first phase relevés containing 365 species (species occurring in fewer than three or less relevés were not included in the analysis) were satisfactorily ordered in a table. This method, therefore, proved satisfactory with a fairly large data matrix. The data matrix, in contrast, proved too large for analysis using homogeneity functions. Initial Braun-Blanquet groups had to be defined prior to further analysis. The homogeneity function tests on these groups showed them to be reasonable. Little further subdivision of these groups using homogeneity functions was effected although the degree of similarity between individual members and groups was readily demonstrated.

The Ceska & Roemer programme for identifiying species-relevé groups only resulted in the delimitation of the major groups which were readily delimitable using less sophisticated and cheaper facilities.

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UITTREKSEL

Monsterperseeldata is versamel in twee fases van 150 *en* 100 *elk, versprei deur byna* 24 000 *ha plantegroei. Assosiasie-analise, Braun-Blanquet en homogenitietsfunksie metodes is op die data getoets. Slegs die "normale" assosiasie-analise metode is toegepas. Drie metodes van datasortering vir tabulering is getoets en is vergelyk met 'n vierde metode. Homogeniteitsfunksies is gebruik om 'n dendrogram op te trek en om die graad van ooreenkoms tussen die individuele monsterpersele en groepe daarvan te bepaal. Die verskillende metodes word vergelyk. Die Braun-Blanquet metode is gereeld meer doeltreffend en presies as die ander metodes getoets in die floristies ryk plantegroei van die Suidwes Kaap Provinsie van Suid-Afrika.*

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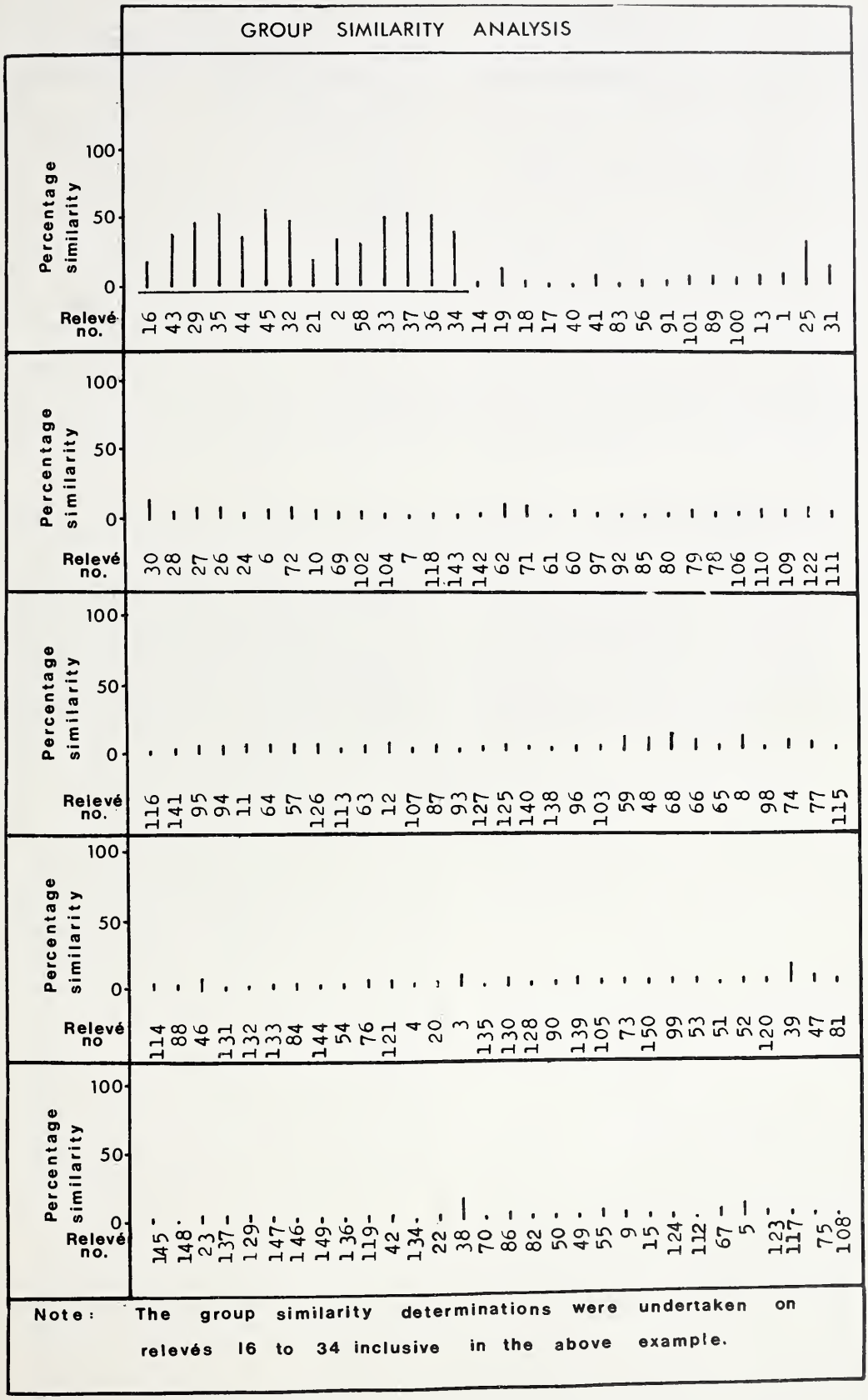


FIG. 4.—Group similarity analysis from Boucher (1972).

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A preliminary account of aerial plant biomass in fynbos communities of the Mediterranean-type climate zone of the Cape Province

F. J. KRUGER*

ABSTRACT

Aerial plant biomass has been sampled by harvesting on several sites in fynbos communities of the south-western Cape Province.

Biomass in stands of about two years old ranged from about 2 200 kg per ha to about 7 500 kg per ha. Mature stands comprised about 11 000 to 15 000 kg per ha in heaths and 15 000 to 26 000 kg per ha in sclerophyllous scrub. The data indicate a maximum annual growth rate of 1 000 to 4 000 kg per ha early in the development of a stand, but growth rates appear to decline rapidly as communities age.

Young stands are dominated by hemicryptophytes, which comprise about 2 000 to 6 000 kg per ha, or about 60 to 75 per cent of the biomass in stands of about four years old. Shrubs become prominent later, but the hemicryptophytes persist.

The data indicate that the biomass, growth rates and the shape of the growth curves of fynbos communities are on the whole similar to those of analogous vegetation in other zones of mediterranean type climate. However, there are important structural differences in that analogues of the northern hemisphere (garrigue, chaparral) do not have a significant component of persistent hemicrytophytes. Although Australian heath communities do have this feature, the hemicryptophytes are not as prominent as in fynbos.

RESUME

RAPPORT PRELIMINAIRE SUR LA BIOMASSE DE LA VEGETATION AERIENNE DANS LES MAQUIS (FYNBOS) DE LA ZONE CLIMATIQUE DE TYPE MEDITERRANEEN EN PROVINCE DU CAP

On a obtenu un échantillonnage de la biomasse de la végétation aérienne en en récoltant à divers endroits du maquis (fynbos) du sud-ouest de la Province du Cap.

Dans des stations vieilles d'environ 2 ans la biomasse a varié de 2 200 à 7 500 kg par ha (approximativement). A maturité, ces chiffres se montent à 11 000–15 000 kg par ha dans les bruyères et 15 000–26 000 kg par ha dans les brousses sclérophylles. Les données indiquent un taux de croissance annuel maximal de 1 000 à 4 000 kg par ha au début du développement d'une station, mais les taux de croissance semblent diminuer rapidement quand les communautés vieillissent.

Les jeunes stations sont dominées par des semi-cryptophytes qui comprennent environ 2 000 à 6 000 kg par ha, ou de 60 à 75 pour 100 de la biomasse dans des stations âgées d'environ quatre ans. Plus tard les arbrisseaux prédominent mais les semi-cryptophytes persistent.

Les données indiquent que la biomasse, les taux de croissance et la forme de la courbe de croissance de ces maquis sont au total semblables à celles des associations végétales analogues dans d'autres zones du type climatique méditerranéen. Néanmoins, il y a d'importantes différences structurelles en ceci que les analogues de l'hémisphère Nord (garrigue, chaparral) n'ont pas une constituante significative de semi-cryptophytes persistants. Bien que les associations de bruyères australiennes possèdent cette caractéristique, les semi-cryptophytes n'y sont pas aussi importants que dans le fynbos.

INTRODUCTION

The ecology of natural communities of Mediterranean-type ecosystems has recently received considerable attention, particularly from the point of view of ecosystem convergence, and much more information on plant communities has become available (Specht, Rayson & Jackman, 1958, and previous papers; Specht, 1969a, 1969b; Jones *et al.*, 1969; Mooney *et al.*, 1970; di Castri & Mooney, 1973). However, few data on the Cape fynbos† have reached the press.

In this paper data have been collated on the biomass of fynbos communities, which have become available during the course of ecological studies from 1967 to 1974. The studies were not aimed at measuring community production nor are the data such that they may be used as direct measures of productivity. Nevertheless, they represent an index of productivity and contain other useful information.

STUDY AREAS

Biomass surveys were conducted on various sites in three research areas, each described below.

1. **Jonkershoek Forest Research Station** (sites 1.1–1.4). The research area at Jonkershoek is situated at about 33°57′S and 18°55′E. The ecosystem has been described by Wicht *et al.* (1969). The communities sampled are situated on the slopes and near the bottom of a steep-walled valley (Fig. 1) and occur on soils derived from Cape granites. Soils are about one metre deep with a brown structureless loam A-horizon on a yellow-brown apedal B. They are acid, with pH ranging from about 4,50 to 5,00. Extractable phosphorus (citric acid extract) amounts to about 12 to 40 p.p.m. and total nitrogen and organic carbon content amount to 0,1 to 0,2 per cent and three to eight per cent respectively, in the A-horizon (Joubert, 1965).

2. **Zachariashoek Research Catchment** (sites 2.1–2.3). This catchment research area is situated at 34°49′S and 19°02′E and has been described by van der Zel (1974). The communities studied are situated in the Kasteelkloof subcatchment (Fig. 2). Soils are derived from sedimentary orthoquartzites and shales of the paleozoic Table Mountain Group. The soils here have not been studied, but would resemble those at Jakkalsrivier rather than those at Jonkershoek. Site 2.2 is phreatic and the soil has an organic A-horizon.

Few climatic data are available. Rainfall at the top of the catchment amounts to about 1 300 mm per annum, and at the bottom, 1 100 mm per annum (six-year records at 701 m and 274 m a.s.l., respectively).

3. **Jakkalsrivier Research Catchment** (sites 3.1–3.10). Plathe & van der Zel (1969) and Kruger (1974) have described the Jakkalsrivier area in some detail (Fig.

* Jonkershoek Forest Research Station, Stellenbosch.

† Also known as sclerophyll bush (Adamson, 1938), and including the types described by Acocks (1953) as Macchia, False Macchia and Coastal Macchia.



FIG. 1.—View of sclerophyllous scrub community at site 1.2, Jonkershoek, shortly after sampling. Prominent shrubs are *Rhus tomentosa* and *Anthospermum aethiopicum*. Asteraceae dominate the lower shrub stratum.



FIG. 2.—View of open sclerophyllous scrub community at Zachariashoek (site 2.1) at age five years. Here, the sclerophyllous shrubs have not yet emerged and the community is dominated by Restionaceae: *Chondropetalum paniculatum, Hypodiscus argenteus* and *Cannomois virgata* are prominent.



FIG. 3.—View of microphyllous evergreen dwarf scrub (low heath) community at Jakkalsrivier (site 3.7), at age 14 years. The shrub stratum is dominated by *Erica hispidula*.

3). It is centred at 34°09'S and 19°09'E. Soils are derived from the orthoquartzites and shales of Table Mountain Group. In most cases, these are coarse rocky sands with a humic A-horizon, dystrophic, with pH ranging from 3,5 to 5,0, total exchangeable cations from 0,2 to 7,9 me/100 gm, and cation exchange capacity from 0,5 to 44,0 me/100 gm. Base saturation is very low. Phosphorus is present at about one to four parts per million (Bray No. 2 extract). Total nitrogen ranges from 0,01 to 0,1 per cent, and organic carbon from about two to four per cent, in the A horizon.

The principal climatic features of Jonkershoek and Jakkalsrivier are illustrated by means of Walter diagrams (Walter, 1963) in Fig. 4. The mean total radiation for the region is 450 to 500 cal per square centimetre per day. Table 1 summarizes the principal physical features of the sample sites, and includes names of plant communities. Fosberg's (1967) structural-functional classification was used and refers to the mature community. Community names based on character species are given where possible and are those assigned in prior studies (Kruger, 1972; 1914). Figs. 1, 2 and 3 illustrate typical communities.

METHODS

Communites which appeared structurally homogeneous were selected for sampling. Stratified random sampling was used wherever conditions permitted, and in these cases a ranked-set sampling procedure (Halls & Dell 1966) was followed. Most samples were collected in late summer or early autumn, when the communities are nearly dormant. Successive harvests were completed on sites 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6.

Biomass was determined by clipping aerial plant parts from one-metre-square quadrats in all cases except site 1.1, where 0,5 m² plots were used, and the six-year stand at 2.2, where 2,5×2,5 m plots were used. In most cases an apparatus described by Hetherington (1967) was used to define the cylinder within which material was collected. Plants were

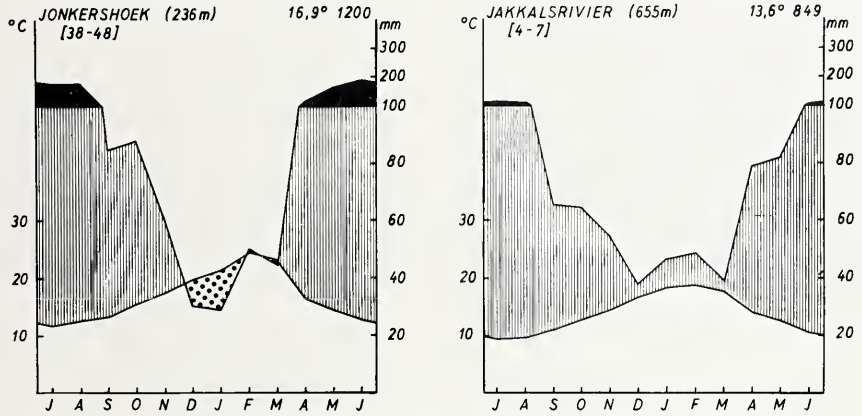


FIG. 4.—Walter diagrams for Jonkershoek (Manor House Station) and Jakkalsrivier (Main Station).

TABLE 1.—Communities and physical factors for each sample site

Site no.	Alt. metres	Aspect (slope, azimuth, degrees)	Slope, degrees	Geology	Community
1.1.....	405	218	14	Cape granite.....	Mesophyllous evergreen broad sclerophyll scrub.
1.2.....	250	24	17		
1.3.....	250	24	17		
1.4.....	250	24	17		
2.1.....	630	195	23	Quartzite, T.M.G.....	Mesophyllous open evergreen broad-sclerophyll scrub; *Cannomois virgata-Hypodiscus albo-aristatus* Community.
2.2.....	510	121	22	Quartzite, T.M.G.....	Evergreen broad-sclerophyll swamp scrub; *Elegia thyrsifera–Osmitopsis asteriscoides* Community.
2.3.....	360	98	23	Tillite & shale, T.M.G.....	Mesophyllous open evergreen broad-sclerophyll scrub; *Montinia caryophyllacea–Helichrysum tomentosulum* Community.
3.1.....	870	156	15	Quartzite, T.M.G.....	Microphyllous evergreen dwarf scrub(heath); *Willdenowia sulcata–Protea cynaroides* Community.
3.2.....	1 065	132	34	Quartzite, T.M.G.....	Open microphyllous evergreen scrub (heath); *Willdenowia sulcata–Klattia partita* Community.
3.3.....	880	238	27	Quartzite & shale, T.M.G.	Mesophyllous evergreen broad-sclerophyll scrub and heath; *Tetraria bromoides–Erica plukeneti* and *Willdenowia sulcata–Protea cynaroides* Communities.
3.4.....	865	195	17		
3.5.....	785	248	18	Tillite & shale, T.M.G.....	Mesophyllous evergreen broad-sclerophyll scrub; *Tetraria bromoides–Erica plukeneti* Community.
3.6.....	850	98	15	Quartzite, T.M.G.....	Microphyllous evergreen dwarf scrub (heath); *Tetraria thermalis–Hypodiscus aristatus* Communities.
3.7.....	785	81	5		
3.8.....	815	317	22		
3.9.....	745	263	19		
3.10.....	740	280	20		

TABLE 2.—Aerial plant biomass statistics for each site

Site no.	Age	Sample size	BIOMASS (KG/HA)						Coefficient of variation (%)	Std deviation, total biomass	Confidence interval (P=0,95)	Litter mass (Kg/ha)††
			Shrubs	Sub-shrubs	Graminoid	Restioid	Herbs	Total				
1.1	6 yrs 3 mo	20	—	—	—	—	—	15704	14,9	2341	1 096	—
1.2	17 yrs	9	—	—	—	—	—	25 700	43,1	11 080	17 034	—
1.3	10 yrs	9	—	—	—	—	—	18 430	37,0	6 82º	10 499	—
1.4	10 yrs	9	—	—	—	—	—	13 078	55,7	7 280	11 192	—
2.1	6 yrs	18	1 016	—	1 029	4 951	264*	7 260	—†	—†	—†	994
2.1	1 " 9 mo	18	424	20	573	1 982	248	3 247	66,0	2 144	2 134	—
2.2	6 "	6	10 581	—	1 597	8 527	643*	21 349	—†	—†	—†	4 950
2.2	1 " 9 mo	18	1 963	913	2 207	2 194	297	7 574	56,4	4 273	4 253	≈0
2.3	6 "	18	1 081	—	1 992	2 089	570*	5 731	—†	—†	—†	2 385
2.3	1 " 9 mo	18	167	95	1 140	523	306	2 230	28,8	643	640	≈0
3.1	3 " 4 mo	18	414	739	3 028	1 711	683	6 574	40,3	2 652	2 639	≈0
3.1	4 " 4 mo	18	310	810	3 554	2 719	980	8 373	33,9	2 839	2 826	≈0
3.2	4 " 4 mo	18	3 014	425	2 013	2 830	986	9 226	35,8	3 319	3 303	≈0
3.3	4 " 1 mo	18	981	358	2 201	1 990	735	6 264	24,8	1 555	1 548	≈0
3.4	3 " 3 mo	18	1 013	446	1 377	1 543	550	4 928	36,0	1 773	1 765	≈0
3.4	4 "	18	703	1 177	1 453	2 405	898	6 636	26,0	1 726	1 718	≈0
3.5	3 " 6 mo	18	1 196	790	1 744	1 605	400	5 736	35,5	2 037	2 028	≈0
3.5	4 " 4 mo	18	1 728	740	1 592	2 303	609	6 972	29,1	2 030	2 020	≈0
3.6	3 " 7 mo	18	656	169	1 301	1 994	730	4 850	35,0	1 697	1 689	≈0
3.6	4 " 4 mo	18	691	166	1 256	2 968	985	6 065	27,3	1 653	1 645	≈0
3.7	16 "	18	3 253	≈0	1 819	6 946	347	12 365	49,3	6 093	6 064	2 230
3.8	16 "	18	3 062	12	4 246	4 469	1 109	12 987	72,3	9 326	9 282	3 819
3.9	16 "	18	5 710	≈0	1 397	3 564	401	11 072	28,8	3 190	3 175	2 318
3.10	16 "	9	7 627	97	1 146	4 184	1 475	14 529	34,0	4 932	7 582	2 412

* Includes sub-shrubs.
† Could not be calculated—non-random samples.
†† Dash = could not be collected; = 0 = trace collected.

clipped as close to the soil surface as possible, using secateurs. If litter was present in significant quantities, it was collected by raking the soil surface with the fingers. Dead plants were included as litter. Clipped material was segregated into growth-form categories during the clipping routine. The plant material was stored in 2 mm-mesh plastic-coated fibre-glass gauze bags and hung in a well-ventilated place until it could be treated in the laboratory.

The categories used for the segregation of clipped material are detailed below.

(i) Shrubs: microphanerophytes and nanophanerophytes of families such as Proteaceae, Ericaceae and Leguminosae.

(ii) Sub-shrubs: sub-ligneous nanophanerophytes and chamaephytes of genera such as *Stoebe* and *Metalasia* (Asteraceae).

(iii) Graminoid: hemicryptophytes typical of Poaceae and Cyperaceae.

(iv) Restioid: leafless hemicryptophytes of the family Restionaceae and, sometimes, Cyperaceae, described as assimilating stem type hemicryptophytes by Adamson (1931).

(v) Herbs (forbs): non-ligneous elements not included in above categories, and including ferns.

In the laboratory the fresh mass of the contents of each bag was determined before the material was chopped mechanically in lengths of 0,5 to 3,0 cm. A sample of four 50–100 gm units was drawn from the chopped material after thorough mixing. The moisture content of these was determined by normal oven-drying procedures (105°C for 24 hours). The mean moisture content of the subsample was used to estimate the oven-dry mass of the original material.

Table 2 includes the 'age' of the communities. This represents the time since the last burn and closely approximates the real age of the shrubs that have regenerated from seed. Age was determined from Department of Forestry records or, where this was not possible, by node-counts on Proteaceae as described by van der Merwe (1969).

RESULTS AND DISCUSSION

Data are presented in detail in Table 2 and further depicted in Fig. 5. The curves in Fig. 5 were drawn by hand and fitted to represent the approximate upper and lower limits of the data set.

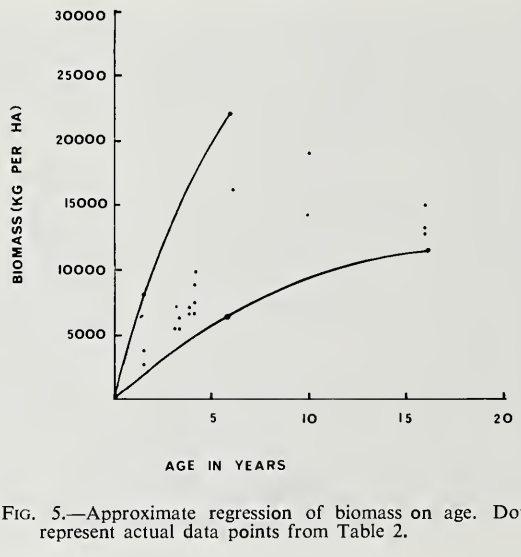


FIG. 5.—Approximate regression of biomass on age. Dots represent actual data points from Table 2.

Sample efficiency

The coefficients of variation for total biomass shown in Table 2 clearly indicate that, in many cases, random samples of clipped quadrats need to be large for reasonably precise biomass estimation. The number of sample units used here was seldom adequate to ensure a confidence interval equal to or less than 20 per cent of the mean, at five per cent probability of error. For a confidence interval of 20 per cent of the mean, about thirty to sixty quadrats would be required (and in some cases a great deal more). Furthermore, the samples were not large enough to show a significant difference (at P=0,95) between harvests in successive years on the same site, though the vegetation had obviously grown.

These estimates are much less precise than those reported by Jones & Specht (1967) and Jones (1968), who obtained estimates with 95 per cent confidence interval of about 12 per cent of the mean, using 12 to 20 one-metre-square quadrats. These authors concluded that successive harvests were not appropriate in production studies in heath.

Since the information reported here was collected with the aim of monitoring long-term trends in

biomass, it was not thought profitable to improve precision by increasing sample size. Nevertheless, future studies would benefit if larger quadrats were used. Where greater precision is required and alternative techniques of production measurement (such as gas-exchange measurement) are not feasible, a combination of sampling by vegetation strata and allometric subsampling of dominant species populations should solve some of the problems due to heterogeneity in fynbos communities.

Precision in these data sets is felt adequate for the purposes of this discussion.

Rates of growth

Fig. 5 may be used to indicate means and ranges in the rate of growth of fynbos communities. The data do not cover a full range of fynbos communites: old stands of tall sclerophyllous scrub are hardly represented. Nevertheless, a reasonable picture has emerged. The highest rate was exhibited by the phreatic community at site 2.2—about 4 000 kg per ha per annum during the first two years. In contrast, the heath community in the same locality, at site 2.3, grew at about 1 000 kg per ha per annum during the same period. These values are close to the upper and lower limits of mean annual increment represented by the curves in Fig. 5. A rate of 2 500 kg per ha per annum appears to be a reasonable average.

Growth rates appear to fall off rapidly as communities age.

Sclerophyllous scrub (represented by sites 1.1 to 1.3) would seem to grow about as fast as the phreatic community, although that at Jakkalsrivier (site 3.5) appears subnormal. Heath communties show rates between normal and the minimum.

Fynbos as fuel

Fynbos communities readily sustain a running fire under average summer conditions once they have reached four years of age and may burn at three years under severe fire hazard conditions.

Several communities of about four years old have been sampled. These had biomasses of about 5 000 to 10 000 kg per ha, which may be accepted as reasonable minimum fuel levels for a successful burn. Site 3.4, with about 7 000 kg per ha at four years, sustained a hot fire in a prescribed burn 11 months later.

At four years of age most communities are dominated by graminoid and restioid plants. These are all fine fuel (i.e. with particle diameters less than six millimetres). Furthermore, cured material forms a significant proportion of the fuel after the second or third year when leaves and stems from the first and second growing seasons die, but remain attached and erect for a further one or two seasons. At this stage, therefore, the vegetation provides a fine, porous but reasonably compact fuel bed, much like a grassland fuel. This would explain why they burn readily at this age in spite of the rather small quantities of available fuel.

The rapid rate of growth of a phreatic community like that at site 2.2 does not necessarily imply inflammability at an earlier age. Plant material in such communities is green and does not cure readily in the early stages: in fact, an inflammable stage is often delayed longer than in other communities.

Heaths from Jakkalsrivier have a low biomass (11 000 to 15 000 kg per ha at 16 years), but dead plants and litter can comprise up to a quarter of the total. As a result, and because the communities are dominated by plants with fine leaves and branches, they burn fiercely under dry conditions, and fires are often extremely difficult to control.

The mature sclerophyllous scrub communities at Jonkershoek provide considerably more fuel, but much of this is coarse and available only under extreme fire hazard conditions.

Community structure and development

Most plants in the fynbos sprout after fire (Wicht, 1945; van der Merwe, 1966). The graminoid and restioid plants are almost all of this nature, whereas many shrubs and subshrubs are not. Communities in the early stages are dominated by the former (which comprise about 60 to 75 per cent of the biomass at three to four years) and the vegetation has the physiognomy of a grassland. Since individual shoots and leaves of the hemicryptophytes do not live longer than about two years, and fall after another two years, this component reaches its maximum in about the fourth year. Thereafter woody elements become prominent if conditions are suitable, although herbs persist and maintain their biomass for many years. Communities on moist or wet sites (as at 2.2 and 3.3) have a rather different initial physiognomy, since they frequently contain a high proportion of sprouting shrubs, which reach early prominence in development.

CONCLUSION

Considerable data on growth and biomass of shrub communities in mediterranean type ecosystems have become available recently.

Specht (1969a, 1969b) has compared analogous communities from the southern regions of France, California and Australia. He estimated mean annual increments (M.A.I.) for the first five years after fire, as follows:

	M.A.I. kg per ha
Montpellier	4 200
San Dimas	1 200
Dark Island, S. Australia	640
Southern Victoria	1 500

Maximum biomass reported was about 49 700 kg per ha at 13 years for garrigue, and 49 100 at 37 years for chaparral (of which 21 800 kg consisted of standing dead sticks).

Specht suggests that his data for the garrigue near Montpellier are atypical, and this is confirmed by Long & Thiault (pers. comm.). Data from more typical garrigue indicate a mean annual increment of about 1 400 kg per ha per annum during the first six years, and total biomass of about 15 000 kg per ha at 18 years (Long *et al.*, 1967 in Specht, 1969b; Long & Thiault, pers. comm.). These also show that the garrigue growth curves also resemble the typical cases illustrated by Specht (1969b) and Jones *et al.* (1969).

Aerial biomass of an evergreen chaparral community of unspecified age at Echo Valley, California (mean annual precipitation 450 mm) amounted to 23 000 kg per ha; that of a similar community on a similar site in Chile amounted to about 7 400 kg per ha (Mooney, pers. comm.).

Jones *et al.* (1969) have collated growth data for Australian heath communities. They produced two curves for growth of aerial portions of the communities, one representing the drier and the other the wetter limits of the geographical range of heat in Southern Australia. Growth rates during the first five years amount to about 800 kg per ha per annum in the first instance, and 1 500 kg per ha per annum

in the second. Maximum biomass for coastal sites was about 16 000 kg per ha at 18 years (sand heath at Tidal River, Victoria). They caution that: "The growth curves do not necessarily indicate the maximum production of each site. This may be influenced by the development (or invasion) of taller-growing species". Such cases are reported by Specht *et al.* (1958). Communities dominated by *Banksia ornata* have a biomass of almost 20 000 kg per ha at 15 years of age.

The data for fynbos are similar to those for analogous communities in other areas with mediterranean type climates. The curves in Fig. 5 indicate a minimum rate of growth of about 1 000 kg per ha per annum, and a maximum of 3 400, over the first five years after fire. The most vigorous community is that on the phreatic site (2.2), but the maximum biomass measured is that of a 17-year old sclerophyllous scrub community at Jonkershoek: this is about the same as that of the 18-year old chaparral community sampled by Specht. The mature heath communities at Jakkalsrivier, however, have a lower biomass than all those of equivalent age studied elsewhere except the mallee-broombush (Specht, 1969b), which is not a good fynbos analogue.

On the whole the figures support Specht's conclusion that "The growth rates of these distinctive plant communities, composed of entirely different species, are largely controlled by the major factors—solar radiation and available water. In similar homoclimes essentially the same growth rate results." More information is necessary to explain differences within the data sets, but there is good evidence that soil moisture availability overrides the effect of soil fertility, and that community production is strongly affected by the presence or absence of tall long-lived shrubs, at least in Australia and South Africa.

Data for the biomass of growth-form categories in fynbos stands provide a limited basis for comparisons of community structure. They do indicate that persistent perennial herbs, particularly hemicryptophytes, are a feature which distinguishes fynbos from northern analogues. Chaparral is known for the rich herbaceous annuals which appear after fire, with peak abundance within one to five years, and disappear almost completely thereafter (Sweeney, 1956; Vogl & Schorr, 1972; Mooney & Parsons, 1973; Biswell, 1974). These comprised 75 and 14 per cent respectively of total live biomass in one- and three-year old chaparral sampled by Specht (1969b), but were absent in the nine-year old stand.

The herbaceous flora of the mediterranean maqui and garrigue also respond strongly to fire, but include perennials which persist in old stands in small quantities (Naveh, 1974; Long & Thiault, pers. comm.), though their biomass is never large. The communities studied by Specht were dominated from the start by phanerophytes and chamaephytes: herbs amounted to 30 per cent of total biomass in the first year after fire, of which hemicryptophytes contributed about 500 kg per ha or 10 per cent of total biomass. The hemicryptophytes became insignificant after the sixth year of development, but other herbs persisted. Long & Thiault report that biomass of herbs may often be over 10 per cent of the total in the first year.

In fynbos, herbs contribute up to about 4 500 kg per ha after two growing seasons; as noted, hemicryptophytes dominate communities up to at least four years after burning. Herbs in sixteen-year old heaths have biomasses up to 8 000 kg per ha, with restioid and graminoid plants predominant.

Australian communities are similar in this respect, but the perennial herbaceous component is not as large as in fynbos. Data from a "sand heath" at Frankston, Victoria (Jones & Specht, 1967; Jones, 1968) show that hemicryptophytes (Restionaceae and Cyperaceae) reached a maximum of about 2 100 kg per ha at four years, comprising about 32 per cent of the biomass. At eight years the proportion was 26 per cent. Comparative studies on Wilson's Promontory in the same State (Groves & Specht, 1965) showed that hemicryptophytes in a "wet heath" had twice the mass of those in a " sand heath" (2 000 vs 1 000 kg per ha), but persisted in old (twelve-year) stands in both cases. Specht *et al.* (1958) noted, of Dark Island "sand heath", that certain understorey plants including hemicryptophytes regenerate rapidly after fire and persist for 25 years in the ageing community. Some Restionaceae and Cyperaceae continue to increase as the community develops, but the biomass of the herbaceous elements does not appear to have exceeded about 1 000 kg per ha.

Certain Australian communities of infertile soils, such as the *Gymnoschoenus* hummock sedgelands or "Button-grass plains" and Restionaceous sedgelands of Tasmania (Jackson, 1965; 1972; Paton & Hosking, 1975) and forb heaths of Southern Queensland (Coaldrake, 1961) have a high proportion of perennial hemicryptophytes, and resemble fynbos in this way.

Fynbos and the Australian equivalents therefore have a characteristic persistent herbaceous component, which distinguishes them from analogous shrublands elsewhere, but they differ in that the component is more prominent in the former.

ACKNOWLEDGEMENTS

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UITTREKSEL

Bogrondse plantbiomassa van fynbosgemeenskappe is bemonster op verskeie groeiplekke in die suidwestelike Kaapprovinsie.

Biomassa van opstande met 'n ouderdom van ongeveer twee jaar wissel van omtrent 2 200 kg per ha tot 7 500 kg per ha. Volwasse opstande bestaan uit om en by 11 000 tot 15 000 kg per ha in heideveld, en 15 000 tot 26 000 kg per ha in sklerofiele struikgemeenskappe. Die data toon 'n maksimum jaarlikse aanwas van 1 000 tot 4 000 kg per ha in jong opstande, maar groeitempo's neem waarskynlik vinnig af soos gemeenskappe ouer word. Jong opstande word gedomineer deur hemikriptofiete, waarvan die massa ongeveer 2 000 tot 6 000 kg per ha beslaan, d.w.s. 60 tot 75 persent van die biomassa in die opstande van min of meer vier jaar oud. Struike word prominent in ouer opstande alhoewel die hemikriptofiete bly voortbestaan.

Volgens die data is die biomassa, aanwas en vorm van groeikurwes van fynbosgemeenskappe oor die

algemeen dieselfde of gelykstaande aan dié van gelyksoortige plantegroei in ander wêrelddele met 'n mediterreense klimaattipe (garrigue, chaparral). Daar is egter belangrike strukturele verskille. Die analogiese plantegroei van die noordelike hemisfeer bevat nie 'n beduidende deel van hemikriptofiete nie. Alhoewel die Australiese 'heide'-gemeenskappe hierdie eienskap vertoon is die hemikriptofiete nie so prominent as in fynbos nie.

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Silene dewinteri, a new species of the Caryophyllaceae from the south-western Cape

GILBERT BOCQUET*

ABSTRACT

A new species of *Silene*, *S.* **dewinteri** Bocquet, is described from the sand-dunes of the coastal region of the south-western Cape. The species is closely related to *S. crassifolia* L. and *S. clandestina* Jacq.

RESUME

Une nouvelle espèce de Silene, S. **dewinteri** *Bocquet, est décrite des dunes de sable de la côte du sud-ouest de la province du Cap. Elle est étroitement apparenté aux* S. crassifolia *L. et* S. clandestina *Jacq.*

INTRODUCTION

During the course of a journey undertaken to collect material for a revision of the South African species of the genus *Silene*, I had the opportunity of collecting extensively in the region of Cape Town. One of the localities visited was the coastal area in the vicinity of Table View, 18 km north of Cape Town. This is one of the localities often cited by Ecklon and Zeyher in their "Enumeratio" (1834) under the name of "Rietvalley" or "Riedvalley". I was trying to trace an elusive species listed as "*Silene Constantia*" in Ecklon and Zeyher's work—a species closely related to *S. clandestina* Jacq. I found the plant growing in populations on the sand dunes of the coast between Table View and Melkbosstrand mostly side by side with populations of *S. crassifolia* L.

The plant is an annual species with a spreading habit, fleshy leaves, thickened calyx and protruding calyx nerves. Unfortunately, the name *S. constantia* cannot be given to this species, because it applies to another species (see p.000 under Nomenclature). I therefore name the plant *S. dewinteri* in honour of Dr B. de Winter, Director of the Botanical Research Institute, Pretoria.

DESCRIPTION

Silene dewinteri *Bocquet* sp. nov., *S. clandestinae* Jacq. valde affinis, a quo tamen habitu diffuso, foliis crassis, calyce incrassato nervis prominentibus differt.

S. constantia Eckl. & Zeyhr., Enum. 32 (1834), quoad descr., typo et synonymia excludendis.

Radix simplex, tenuis. *Caulis* 7–20 cm altus, e basi ramosus, ramis expansis, procumbentibus, interdum quasi geniculatis, pilis retrorse appressis. *Folia* anguste elliptica vel anguste oblanceolata, 3–6 (–10)× 15–40 (–60) mm magna, plus minusve hirta, marginibus hirtis, basin versus ciliatis, succulenta, circa 1 mm crassa, id est statu sicco valde rugata. *Racemus* 3–7-florus, floribus secundis, primum vix cernuis, maturitate fructus perfecta erectis. *Calyx* incrassatus, hirsutus, anthesi campanulatus et 4–5×12 mm, maturitate fructus conspicue clavatus et tum 5–6×12 mm magnus, nervis crassis prominentibusque. *Petala* bifida, ungue calycem breviter superante, in fauce appendicibus binis 0,5–1 mm altis praedita, limbo 5–8 mm longo, intus sordide blanco, extus viridescente vel brunnescente. *Gonophorum* 4–5 mm altum, glabrum. *Ovarium* viride, ovoideum, stylis 3 praeditum. *Capsula* brunnea, 3×8–9 mm magna, dentibus 6



FIG. 1.—*Silene dewinteri*. Holotype plant (*Bocquet* 17774) growing on sand dunes at Table View, south-western Cape. The maturing capsules, broader calyx with bulging nerves, thick leaves and spreading habit of the whole plant are evident.

*Eidgenössische Technische Hochschule, Zürich, Switzerland.

se aperiens, calycem maturitate fructus perfecta superans. *Semina* fusca, dorso alis 2 undulatis in ambobus lateribus circumdato. *n=12*. FIG. 1.

TYPE.—Cape Province, Table View, 18 km N of Cape Town, low undulating sand dunes between coastal dune and marshy hinterland, on semi-barren sand in disturbed area near a new settlement, 1975–11–09, *Bocquet* 17774 (ZT, holo.).

The species is endemic to the south-western Cape. See Fig. 2.

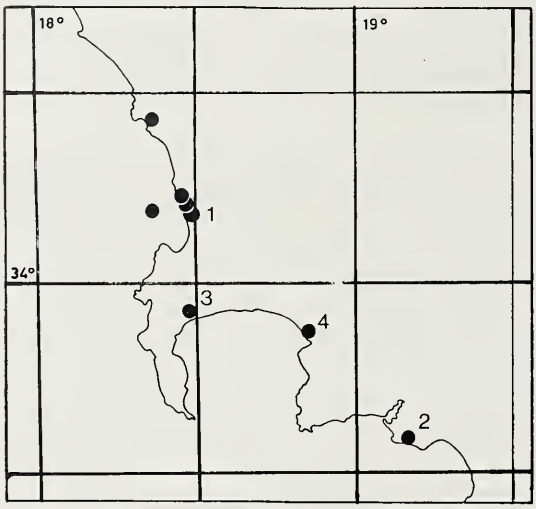


FIG. 2.—Distribution of *S. dewinteri*. 1, type locality; 2, Onrus River Mouth where *Bocquet* 17881 (chromosome count, n=12) was collected; 3 & 4, Ecklon and Zeyher's localities, "prope Constantiam" and "Hottentotsholland".

CAPE.—3318 (Cape Town): Bok Bay, WSW of Malmesbury (–CB), "flowers white", 1940–09–14, *Compton 9389* (NBG); Table Bay, between Bloubergstrand and Melkbosstrand, north of Cape Town (–CD), scattered at the foot of the coastal dune on the sea side, on half-colonized sand, bordering an extensive colony of *S. crassifolia*, 1975–11–09, *Bocquet 17781*; *17783* (ZT; PRE; NBG); seeds and preserved material from same population, *Bocquet 17818* (ZT); Bloubergstrand (–CD), 1954–09–10, *Stokoe 67560* (NBG); Robben Island, N of Cape Town (–CD) 1932–10, *Adamson s.n.* (BOL); Robben Island, 1943–08–20, *Walgate 512* (NBG); Table View, 18 km N of Cape Town (–CD), *Bocquet 17774* (holo., ZT); *17775*; *17776* (Z); "in locis arenosis (alt. 1) collium capensium prope Constantiam et Hottentotsholland" [these two localities are rather indeterminate: they correspond roughly to Muizenberg (–BA) and Strand (–BB)], s.d., *Ecklon & Zeyher s.n.* (NBG). 3419 (Caledon): Onrus River mouth, 7 km W of Hermanus (–AC), sandy areas between bushes on the low undulating dunes between rocky strand and new settlement, very near the shore, locally abundant, 1975–11–17, *Bocquet 17881* (seeds, ZT); *17882* (ZT); "Onrus riv. Sand dunes", 1958–09–28, *Willems 57* (NBG).

OBSERVATIONS

1. *Ecology, biology. S. dewinteri* is an annual growing scattered in the half-colonized parts of coastal dunes, in open localities on semi-stabilized sand. It is often accompanied by *S. crassifolia*, a perennial species, that prefers more unstable sand. The two species are rarely found in mixed colonies: they usually occur in contiguous colonies occupying different ecological situations. The ecological relations between the two species are shown in Fig. 3, a schematized section of the Bloubergstrand locality (*Bocquet* 17781). *S. dewinteri* occupies the immediate foot of the dune, where the sand is half-colonized and semi-fixed, while *S. crassifolia* occurs abundantly on the undulating area between sandbank and dune on very sparsely colonized and entirely unstable sand.

Flowering times are different for the two species: *S. dewinteri* flowers in August and September, and *S. crassifolia* from October to January. A biological barrier therefore exists between the two species. No trace of introgression or morphologically intermediate specimens was observed in the localities visited. *S. dewinteri* seems to be equally distinct from *S. clandestina*. The latter species is also an annual, but is not found as near the sea shore as *S. dewinteri*. *S. dewinteri* seems to be strictly limited to the immediate proximity of the sea.

2. *Taxonomy. S. dewinteri* has rarely been collected, probably because the more common *S. crassifolia* occurs in the same localities and depauperate forms of the perennial *S. crassifolia* can easily be mistaken for the annual *S. dewinteri*.

The affinities are clear: *S. dewinteri* is closely allied to both *S. clandestina* and *S. crassifolia*, but can be distinguished as follows:

(a) from *S. crassifolia* by its annual character, smaller calyx and thin root: *S. crassifolia* always has, even in the youngest stages, a thickened root; the older specimens build up a nearly bulbous root.

(b) from *S. clandestina* by the thicker leaves, clavate, broader and very fleshy calyx, as well as the spreading habit. Material was cultivated in Switzerland under glass from seeds of the three populations *Bocquet* 17818, 17774 and 17881. The plants are somewhat more flaccid and the leaves bigger, but the essential characters can be recognized, namely the thickness of leaves, spreading habit and broader calyx with bulging nerves.

3. *Nomenclature.* Ecklon and Zeyher intended describing our plant as a new species under the name of *S. constantia* (the specific epithet refers to Constantia, a suburb of Cape Town). The description, localities and herbarium material agree with *S. dewinteri* However, Ecklon and Zeyher cited *S. crassifolia* L

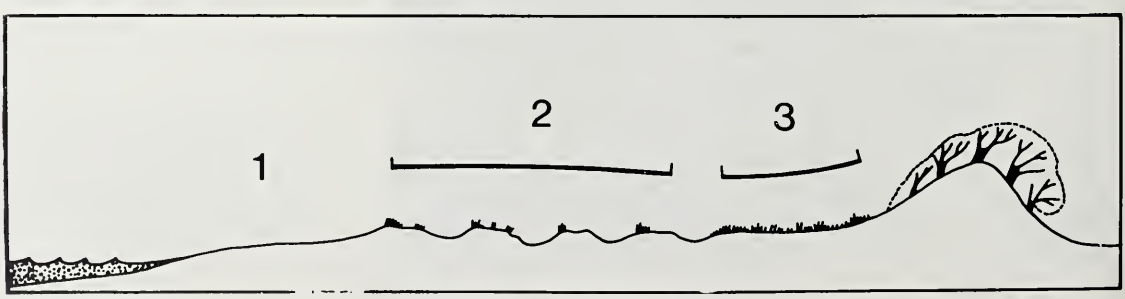


FIG. 3.—Transect of the Bloubergstrand locality (*Bocquet* 17781; 17783). 1, strand; 2, distribution of *S. crassifolia* on the undulating ground in front of the coastal dune (sparsely colonized and unstable sand); 3, *S. dewinteri*, at the foot of the coastal dune (semi-fixed and half-colonized sand).

var. *angustifolia* Bartling (1832) in synonymy and therefore *S. constantia* is automatically typified by the type of this variety. The type specimens of var. *angustifolia* were collected in the vicinity of King's Blockhouse ("Beim obersten Blockhause") on the north-eastern slopes of Devil's Peak above Rhodes Monument. These specimens represent a local form of *S. clandestina*, an ecotype of dry barren hillslopes that is commonly encountered in the Table Mountain and Lion's Head region between 100 and 400 m. It is a small, erect plant with very narrow leaves, but there is no good reason why it should be recognized and described as a distinct infraspecific taxon.

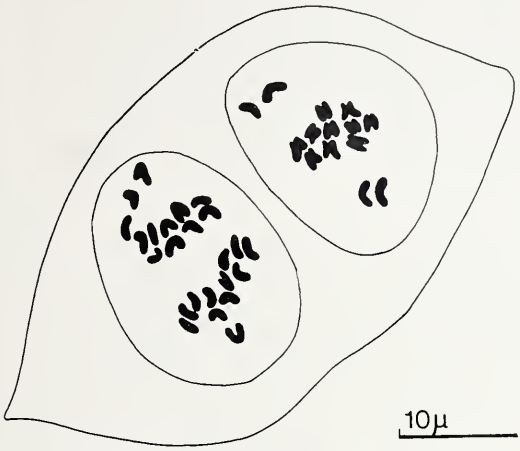


FIG. 4.—*S. dewinteri*. n=12. Anaphase II, microsporogenesis.

4. *Cytology*. Chromosome counts on flower buds of cultivated material yielded the number n=12. Material: *Bocquet* 17881; Carnoy-acetocarmine treatment; 10 counts from 3 slides and 2 buds. Fig. 4 shows an anaphase; the chromosomes are small, but not as contracted as they usually are in meiotic phases of *Silene* species. In most *Silene* species they appear at this stage as more or less isodiametric spots.

ACKNOWLEDGEMENTS

This work has been carried out with the aid of a grant from the Société helvétique des Sciences Naturelles and additional assistance from the ETH-administration. I thank these authorities.

UITTREKSEL

'n Nuwe species van Silene, S. **dewinteri** *Bocquet, word beskryf van die sandduine van die kusstreek van die suidwestelike Kaap. Die species is naverwant aan* S. crassifolia *L. en* S. clandestina *Jacq.*

Bothalia 12, 2: 313–317 (1977)

The taxonomic status of the genus *Rubidgea*

ÉVA KOVÁCS-ENDRŐDY*

ABSTRACT

The genus *Rubidgea* Tate of the fossil family Glossopteridaceae was reduced to a synonym of *Glossopteris* by Seward (1907). Seward's conclusion is now confirmed by a study of a wide range of imprints from a quarry near Hammanskraal, South Africa. The upper and lower surface imprints of a single leaf found on a split fragment of carbonaceous shale provides the main evidence presented. The finely striated upper surface imprint of the leaf could be identified with *Rubidgea*, whereas the lower surface imprint represents the typical strong venation of a *Glossopteris*. The type species of *Rubidgea* is transferred to *Glossopteris* as *G.* **mackayi** (Tate) Kovács comb. nov. The characteristics of upper and lower surface imprints of a number of *Glossopteris* species are discussed.

RESUME

STATUT TAXONOMIQUE DU GENRE RUBIDGEA

Le genre Rubidgea *Tate de la famille fossile des Glossopteridaceae fut considéré par Seward* (1907) *comme un synonyme de* Glossopteris. *La conclusion de Seward se voit confirmée par l'étude d'un vaste éventail d'empreintes en provenance d'une carrière près d'Hammanskraal en Afrique du Sud. Les empreintes supérieure et inférieure d'une même feuille, trouvées sur un fragment de clivage d'un schiste carbonifère, fournissent le principal argument qui est présenté ici. L'empreinte finement striée de al face supérieure de la feuille pourrait être identifiée comme* Rubidgea, *tandis que l'empreinte de la face inférieure présente la forte nervation typique de* Glossopteris. *L'espèce-type de* Rubidgea *est transférée au genre* Glossopteris, *soit:* G. **mackayi** (*Tate*) *Kovács comb. nov. Les caractéristiques des empreintes supèrieures et inférieures de plusieurs espèces de* Glossopteris *sount discutées.*

INTRODUCTION

The family Glossopteridaceae appeared approximately in the Upper Carboniferous and disappeared more or less synchronously in the Lower Triassic. Though the species changed in time due to evolution and adaptation to changing climatic conditions, they are nevertheless generally recognizable as glossopterids. All evidence points to the family Glossopteridaceae of the Order Pteridospermales being a monophyletic and natural group of plants. As in most fossil groups, the classification presents considerable difficulties. Recently doubts have been expressed about the feasibility of a classification of the Glossopteridaceae based on leaf impressions when no cuticles or attached fructifications are available. In this and other papers, the author defends the point of view that taxa, at least at the specific level, may be distinguished by normal taxonomic methods, provided that sufficient good material, which is synchronous, is available and is studied in detail. The basic venation patterns of leaves are typical for all members of the group, but venation characters display definite and useful differences. The fact is that all fossil plants represent once living plants and this realization is necessary for real progress to be made. A knowledge of living extant plants should form an essential part of the equipment of the palaeobotanist.

In the investigation here reported the author has attempted to apply these views to the study of a rich deposit of glossopterid fossils. Special attention is given to the taxonomic status of the genus *Rubidgea* Tate. The material for this study was collected on the farm of Mr J J Brits, 30 km north of Pretoria near Hammanskraal. The carbonaceous shales, in which the leaf impressions are preserved, are of Ecca age. All the specimens studied are deposited in the offices of the Geological Survey, Pretoria, South Africa.

THE IDENTITY OF THE GENUS *RUBIDGEA*

The genus *Rubidgea* was described by Tate in Q. Jl Geol. Soc. Lond. in 1867. The description is as follows:

> "Rubidgea Mackayi, gen. et spec. nov.
>
> Frond oblong, obovate, rounded and obtuse at the apex; secondary veins very slender, very much crowded, dichotomous, oblique. There is no indication of anastomosis of the veins. *Localities.* Bloemkop, near the Sunday's River, Graaff Reinet (Dr Rubidge); East London, at the mouth of the Buffalo River (Mr. McKay)."

In the preamble to this description Tate, however, says the following:

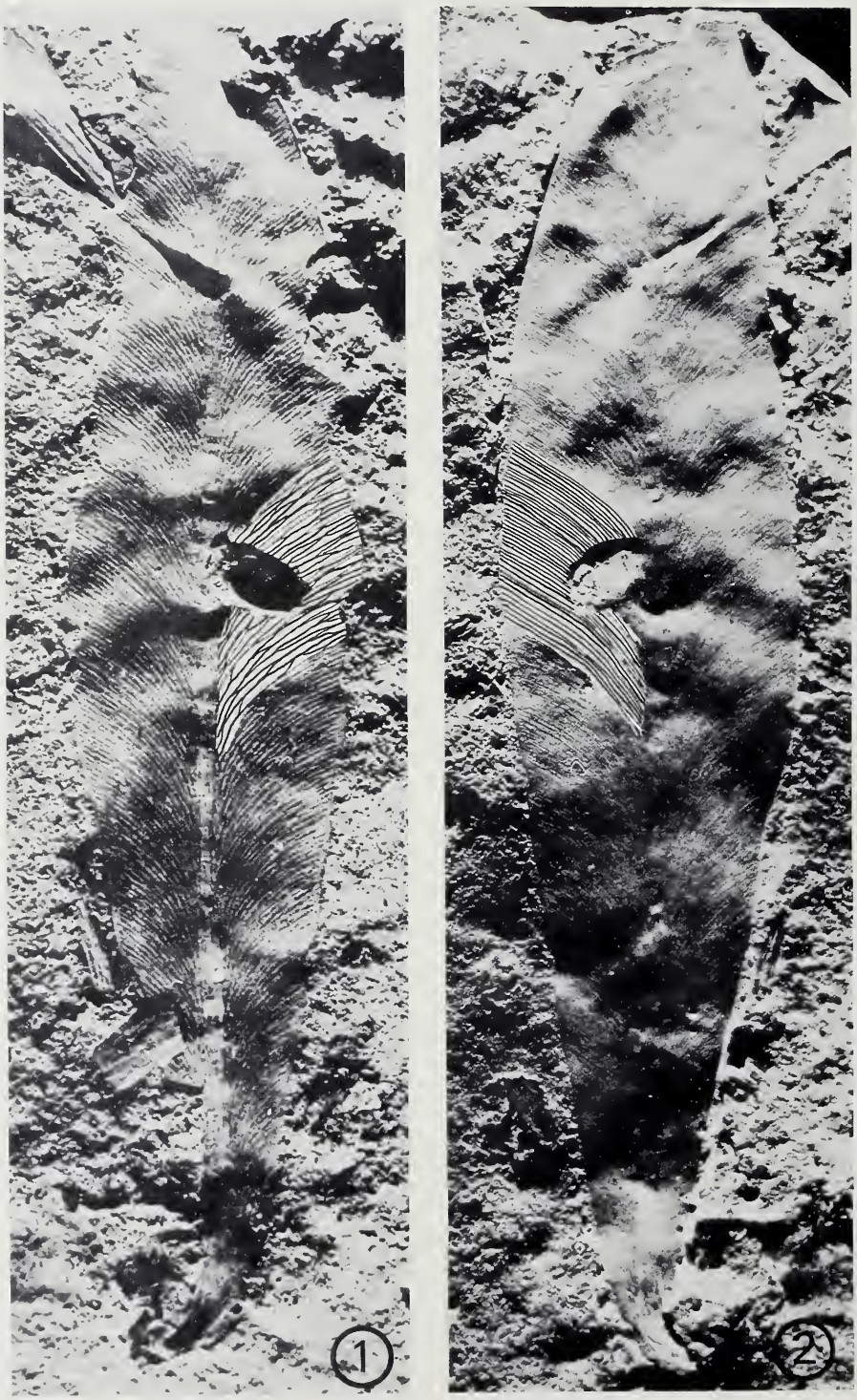
> "With the above-mentioned specimens from Bloemkop are some of an apparently, at first sight, second species of *Glossopteris*; these do not exhibit fructification. Dr Rubidge however, has communicated a drawing (by Mr McKay) of a specimen of this species obtained by Mr McKay near East London: and I find that it presents characters generically distinct from those of *Glossopteris*; for the position of the fructification is indicated by a few large elevated rings, arising from many veins, and somewhat regularly arranged in a row coincident with the margin, and not by numerous spots, small in size, supported by one vein, distributed over much of the surface of the frond".

Whereas the description of the new genus and species is clearly based on the leaf, Tate's comments in the second paragraph quoted here, show that it is only because of the so-called fructifications that he considered creating a new genus. It so happens that the two specimens cited by Tate have, in spite of several searches, not been traced. A comparison of the specimens with the McKay drawing has thus not been possible. It seems clear that Seward (1907), who regards *Rubidgea* as a synonym of *Glossopteris*, also did not see Tate's syntypes. Since the specimens are missing, there seems to be no alternative but to accept the drawing by McKay published by Tate as Plate 5, Fig. 8, as the lectotype of *Rubidgea* Tate. It has already been pointed out by Seward (1907) that the so-called fructifications depicted by McKay, are artefacts and I agree with this view.

THE RELATIONSHIP BETWEEN *RUBIDGEA* AND *GLOSSOPTERIS*

When studying the fossil flora of the Hammanskraal quarry, many leaf impressions were found which show the characteristic venation described and figured by Tate for his genus *Rubidgea*. A venation, such as figured by Tate, is difficult to interpret morphologigically. The very fine veins arise from the median line of the leaf, but are apparently not joined into a true midvein. A closer examination of these *"Rubidgea"* leaves from Hammanskraal shows that some of them exhibit areas of stronger venation with anastomoses typical of the genus *Glossopteris* (Fig. 3). It seems

* Geological Survey, Private Bag 112, Pretoria.



FIGS 1 & 2.—*Glossopteris* sp.* Counterpart "*Rubidgea*". Catalogue Nos HI 103a & b. ×2.

* The species of *Glossopteris* discussed and figured in this paper was recently described by me as *G. pseudocommunis* (1976). However, this name is a later homonym of *G. pseudocommunis* Pant & Gupta (1968) and consequently illegitimate. I therefore rename the species, *G. andreánszkyi* in honour of Professor G. Andreánszky, my mentor in palaeobotany at the University of Budapest.

Glossopteris andreanszki *Kovács*, nom. nov.

G. pseudocommunis Kovács in Palaeontogr. Afr. 19: 81 (1976) non *G. pseudocommunis* Pant & Gupta in Palaeontogr. 124B: 57 (1968).

fairly certain that in these leaves part of the upper surface has decayed or peeled off revealing the nervation of the lower surface. In other instances both kinds of "venation" are seen on the leaf as if superimposed. On these imprints dense and fine lines are visible between the typical *Glossopteris* veins (Fig. 4). Amongst the many slabs of slate split, one showed an almost entire leaf with clear upper and lower surface imprints. These imprints are dissimilar, one being typical of *Glossopteris*, the other of *Rubidgea* (Figs 1 and 2). It is obvious also that the impression of the lower surface, which shows *Glossopteris* characters, represents the imprint of the venation. The very slender lines of the *Rubidgea* imprint, which do not match the nervation of the lower surface, have to be interpreted as fine grooves found on the upper surface of some *Glossopteris* species. The leaves of many extant species of plants would show featureless upper surface imprints, because their veins are not raised. There are many examples of these three states, viz. parts of *Glossopteris* leaves which show *Rubidgea* characters or *vice versa* and both kinds of "venation" next to one another on the same leaf.

These observations indicate that the genus *Rubidgea* and some species of *Glossopteris* were based on impressions of upper and lower surfaces of leaves respectively, *Rubidgea* representing impressions of the upper and *Glossopteris* of the lower surface. There is real proof, therefore, that the genus *Rubidgea* must be regarded as a synonym of *Glossopteris* as concluded, on rather slender evidence, by Seward.



FIG. 3.—*Glossopteris* sp. "*Rubidgea*" surface with patches of *Glossopteris* venation. Catalogue No. HI 10a. ×1,3



FIG. 4.—*Glossopteris* sp. With "fibres". Catalogue No. HI 165. ×3,4.

The study of several glossopterid species of the Hammanskraal fossil flora showed that in all species investigated, except for *G. indica*, the upper and lower surfaces differed in a characteristic and specific manner. In *G. indica* both surfaces were more or less similar. Of the species examined, all leaves with *"Rubidgea"* features proved to belong to the same species (Kovács, 1976). It is possible, however, that other species may also exhibit a *"Rubidgea"* type of upper surface.

As I mentioned before, in some instances the imprint of what appears to be both upper and lower surfaces, can be seen on the same leaf impression (Fig. 4). In such cases there are thinner lines between the strong, anastomosing veins. This feature merits further discussion. Pant (1958) described two new species, namely *Glossopteris fibrosa* and *G. hispida*, based mainly on cuticular examinations. He mentions that *G. fibrosa*: "looks much like many of the figures given by various authors under the names *G. browniana* var. *indica* (*G. indica*), *G. angustifolia, G. browniana* var. *australasica,* (*G. browniana*) and *G. communis* . . . All are clearly different because they lack fibres in vein meshes".

On the evidence of the leaves from Hammanskraal, I interpret such fibres as being the markings of the upper (or "*Rubidgea*") surface showing through on the lower surface. This interpretation is to some extent confirmed by Pant (1958). He mentions that *G. fibrosa* and *G. hispida*, which both show the so-called fibres in the vein meshes, have rather thin laminae. Prior to these studies, differences between upper and lower surfaces of a *Glossopteris* leaf were already reported for *G. browniana* by Dana (1849, p. 717).

In the light of the foregoing, it is of some interest to establish how it has come about that the upper and lower surface leaf impressions were described as separate genera and why, one hundred years later these genera were still being recognized and expanded.

The description and identity of *Rubidgea* have already been discussed. It is clear, as stated before, that Tate believing these plants to be ferns, separated the new genus from *Glossopteris* mainly because of the presence of so-called "fructifications". In his diagnosis of the species he does not comment on the presence of a midrib, but implies this by stating: "secondary" veins very slender, very much crowded. The "secondary" veins arise from the midline of the blade and not from the base, which logically indicates a midvein or a structure resembling a midvein.

Feistmantel's (1881, p. 91) statement when comparing *Palaeovittaria* with *Rubidgea*, viz. "this latter (i.e. *Rubidgea*) showing no indication of a midrib in the lower part", is therefore incorrect. On the drawing by McKay, published by Tate, the lower part of the leaf is missing but, as already indicated, shows the situation where the "secondary" veins arise from the median part of the leaf. In spite of this, *Rubidgea* is still usually characterized by the absence of a midrib as was done recently by Maheshwari (1965, p. 37).

Maithy (1965) accepted *Rubidgea* as a generic entity, but amended it to accommodate several species found in the Karharbari Beds of the Ciridih Coalfield in India. Maithy (p. 42) also starts the description of the venation with the statement "devoid of a midrib". The characterization of taxa such as *Gangamopteris* and *Rubidgea* by the "absence of a midrib", and the failure of authors to refer back to the type specimens, contributed to the confusion which arose. The morphological terms applied to extant plants are not always appropriate to extinct groups: "midrib" does not mean the same in *Glossopteridaceae* as it does, for example, in Angiosperms. *Glossopteris* leaves have a bundle of veins down the middle, but no clear single midrib. When Maithy writes of "numerous veins arising from the median longitudinal position of the frond, occasionally simulating a false midrib", he accurately describes Tate's drawing. Later in his paper, Maithy refers to median veins, however, and omits the important character mentioned in Tate's description, that the secondary veins are very slender and closely crowded together. Ignoring this character, he described two new species, *Rubidgea obovata* and *R. lanceolatus*, both of which have rather strong veins. On the photographs of the leaf impressions of the two species, three of the four leaves have parallel veins fanning out from the narrowed base, yet Mainthy himself chracterizes *Rubidgea* by "veins arising from the median longitudinal position".

At the end of his paper, Maithy indicates that the leaf of *Lanceolatus palaeovittarius* Plumstead "appears to be a *Rubidgea* because no midrib is evident, and the median region of the leaf seems to be occupied by the subparallel veins". In Feistmantel's time the more crowded subparallel median veins of glossopterid leaves were described as a midrib, and it is possible that this condition is found in *Palaeovittaria* Feistm. (1876, p. 368).

In Plumstead's figure (1958, Pl. 16, Fig. 1) the strong, rigid, straight veins clearly do not resemble those of *Rubidgea* as defined by Tate. The leaf of *Lanceolatus palaeovittarius*, however, resembles *Rubidgea lanceolatus*, a fact also mentioned by Maithy. Furthermore it is likely that *Rubidgea lanceolatus* Maithy (Pl. 1, Fig. 5) represents the same species as *Palaeovittaria kurzii* Fstm.

Maithy also mentions *Gangamopteris obovata* Carruthers as a possible *Rubidgea*, because "secondary veins emerge from median veins". Carruthers's figure (1869) depicts a whole leaf and the equally strong subparallel veins radiate from the base. Dr C. R. Hill of the British Museum of Natural History checked the holotype (v.229, Geol. Surv., British Museum Nat. Hist.) at my request. He found the drawing remarkably accurate, except in showing the anastomoses between the veins.

The confusion that exists in the taxonomy of *Glossopteris* and related genera can be attributed to poor descriptions and circumscription of new taxa; to the difficulties inherent in the interpretation of what represents a "midrib" of the leaf of the Glossopteridaceae; and to the fact that the differences in the upper and lower surfaces of glossopterid leaves are usually ignored.

If progress is to be made with the taxonomy of the Glossopteridaceae, these pitfalls will in future have to be avoided.

A NEW COMBINATION IN *GLOSSOPTERIS*

In order to comply with the Rules of Botanical Nomenclature the formal transfer of the type species of *Rubidgea* to *Glossopteris* is hereby made.

Glossopteris mackayi (*Tate*) *Kovács* comb. nov. Basionym: *Rubidgea mackayi* Tate in Q. Jl Geol. Soc. Lond. 23: 141 (1867).

ACKNOWLEDGEMENTS

The author is grateful to Dr S. H. Haughton for critical reading of the manuscript; to Dr B. de Winter thanks are due for useful comments and interesting discussions; to Dr S. Endrödy-Younga for help with

the taxonomy; to Dr A. W. Keyser for his support. The photographs were taken by Dr R. P. Stapleton, Dr H. C. Klinger and Mrs Ruth Fregona.

UITTREKSEL

Die genus Rubidgea *Tate van die fossiele familie Glossopteridaceae is in* 1907 *gereduseer tot 'n sinoniem van* Glossopteris *deur Seward. Seward se opinie word bevestig deur dié bestudering van 'n wye reeks van blaarafdrukke afkomstig van 'n steengroef naby Hammanskraal, Suid-Afrika. Die beste bewys hieroor is vervat in die afdrukke van die onderste en boonste blaaroppervlak van 'n enkele blaar op 'n gesplete fragment van skalie. Die fyngestreepte afdruk van die boonste blaaroppervlak kan met* Rubidgea *geïdentifiseer word, terwyl die afdruk van die onderste oppervlak die tipiese sterk be-aring van 'n* Glossopteris *verteenwoordig. Die tipe-soort van* Rubidgea *word oorgeplaas na* Glossopteris *as* G. **mackayi** (*Tate*) *Kovács comb. nov. Die kenmerke van die boonste en onderste afdrukke van die blaaroppervlakte van 'n aantal* Glossopteris-*soorte word bespreek.*

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Book Reviews

WILD FLOWERS OF NATAL (COASTAL REGION) by JANET M. GIBSON. *Durban: The Trustees of the Natal Publishing Trust Fund.* 1975. Pp. xix+136, 886 colour figures. Price R13,50.

Illustrated books on the flora of Natal are few. One immediately thinks of Wood and Evans's Natal Plants (1898–1912), scientific rather than popular, Mairn Hulme's Wild Flowers of Natal (1954) and Winifred Wright's Ramblers Pocket Guide: Natal (1963). None of these works, however, can claim to have been as acceptable to plant lovers as say Cythna Letty's Wild Flowers of the Transvaal (1962) and some of the books on Cape plants. It is therefore with pleasure that one welcomes two new illustrated works on the Natal flora both of which are reviewed in these pages.

Wild Flowers of Natal (Coastal Region) is written and illustrated by Janet M. Gibson. Initially, Janet Gibson started off by painting the Wild Flowers of the Krantzkloof Nature Reserve near Durban, but was persuaded to enlarge the scope of her work to include the whole of the coastal region of Natal as defined by Ross in his Flora of Natal (1973). In all, Janet Gibson has illustrated 810 species with 886 paintings.

The text is carried on the left-hand pages and relates to the plants illustrated on the opposite pages. The text comprises the family name, binomial and authority, sometimes the common name, cross-reference to the corresponding page in Ross's Flora of Natal, the generic number and brief notes. The notes are generally confined to a description of the habit of the plant, flower colour, frequency and habitat. Up to 12 species are illustrated on a page.

The illustrations in colour are simple and clear, but somewhat stylized. On the whole they tend to be flat without depth; the figures of the *Ipomoea* species on Plates 85 and 86 clearly show this. Globose fruits are given highlights, but the corresponding shadows are often omitted (see fruits of *Solanum giganteum*, Plate 92, 2). White paint has been liberally used to give the impression of highlights but, with reproduction, the white has blurred to give very unrealistic highlight effects (see Plates 27, 5; 60, 1c and 77, 4). Several plants are barely recognizable, for example *Pittosporum viridiflorum* (Plate 38, 1), *Trema orientalis* (Plate 27, 3) and *Trichilia dregeana* (Plate 52, 1a). Janet Gibson has used poster paint, a medium which lends itself to strong reproduction, but does not produce the delicate and life-like effects of water-colour. Although one may not entirely approve of Janet Gibson's technique, one must acknowledge that the illustrations are effective and, after all, this is the important thing.

Two plant names have been incorrectly spelled: *Moraea stewartae* (Plate 18,3) should be *M. stewartiae* and *Scabiosa colombaria* (Plate 104,6) should be *S. columbaria*. S.W. is given as the combining author of *Helichrysum herbaceum*. This is a most unusual abbreviation for Sweet. A printer's devil has set the "1" of C.B. Cl. in roman instead of italics on p. 96.

In spite of the few criticisms mentioned, the reviewer finds this book a most useful and well-presented work—the best available to-day on the flora of Natal and one which is good value for money.

D. J. B. KILLICK

NATAL WILD FLOWERS by BARBARA JEPPE. *Cape Town: Purnell.* 1975. Pp. xiii+118, 56 colour plates, 25 pencil sketches. Price R20.

This book, the second new book on the Natal flora, is written and illustrated by Barbara Jeppe, well-known for her book on the South African aloes and her illustrations in Trees and Shrubs of the Witwatersrand (1964). 248 species are illustrated mainly in colour, but a few are in pencil. Several species are illustrated per plate rather in the manner of Cythna Letty in Wild Flowers of the Transvaal (1962) and Auriol Batten and Hertha Bokelman in Wild Flowers of the Eastern Cape (1966), where the illustrations often overlie one another making a composite picture. As one would expect from an artist, who illustrated so exquisitely common South African weeds for Ciba-Geigy (1975), the paintings are, on the whole, good but spoilt by poor colour reproduction. Barbara Jeppe must have been mortified to see such desecration of her work.

The plants are dealt with family by family. The species are described as follows: common names in English and/or Afrikaans, distribution, brief morphological description in non-technical language, flowering times, cultivation if applicable and sometimes horticultural potential.

The identification of the species depicted cannot be faulted, except in the case of *Brunsvigia natalensis* (Plate 11a), which my colleague, Dr R. A. Dyer, says is certainly *B. undulata* Leighton.

Something went wrong in her description of the family Flacourtiaceae on p. 48. The constituent species do not all have "attractive white flowers crowded at the ends of branchlets" and the family cannot be characterized by the statement that "This shrub is a worthwhile subject as it grows well in cultivation and is frost hard." Obviously Barbara Jeppe was referring to a particular species of Flacourtiaceae, whose name was unfortunately omitted.

Typographical errors are few. The only two noticed were *Acacia Karroo* (capitalization of specific epithet) on p. 52 and E. May. instead of E. Mey. as one of the authors of *Dissotis canescens* on p. 72.

The cover, lay-out and quality of paper used are excellent. Unfortunately the poor colour reproduction will spoil this book for most people. The price of R20 is high, especially if compared with the price of Janet Gibson's book, which covers four times as many species.

D. J. B. KILLICK

VELD PLANTS OF SOUTHERN AFRICA by N. K. HOBSON, J. P. JESSOP, M. C. v.d. R. GINN & JANE KELLY. *Johannesburg: Macmillan South Africa.* 1975. Pp. 310, 110 black and white figures, 110 colour figures. Price R25.

The title of this book is misleading. In the foreword Professor Brian Roberts describes the book as a significant work on our karoo flora. In the introduction the first author, N. K. Hobson, makes no mention of the karoo or karoo plants, but states that the distribution of many of the plants is far flung, embracing all four provinces, South West Africa and neighbouring states. In his "Notes to the text" he makes frequent references to the karoo and its plants. Also, he writes that the "plant colours are those of specimens collected in the Pearston District", which lies in the karoo. In spite of the title, therefore, the book is about karoo plants, some of which are also found outside the karoo. The book appears to be an enlarged and de luxe successor to the authors' successful little book Karoo Plant Wealth (1969). The 50 karoo species included in Karoo Plant Wealth are all included in the present work.

The various features of each of the 109 species are given briefly in the following order: botanical name and author, distribution, origin and meaning of the generic and specific names, common names in English and/or Afrikaans, family name, height, grazing value according to Hobson denoted by 1–5 stars, brief morphological description, frequency, degree to which plant is grazed, regrowth after rain, economic uses and, when available, palatability according to Henrici. Each species is illustrated by means of a black and white habit sketch and a 2× colour close-up painting. Usually four species are illustrated in colour on a page. The book ends with a glossary and index.

The colour illustrations by Michael Ginn are generally good, but sometimes lacking in detail as in Plate 22. The 2× enlargements make some of the plants look grotesque (see *Gasteria* sp., Plate 2). The black and white habit sketches by Michael Ginn and Jane Kelly are poor and, for the most part, are merely wispy impressions of the plants depicted.

There are far too many mis-spelt plant and other names for a book of this class. I counted eight incorrectly spelt plant names, all appearing as captions to the colour figures. There are annoying cases of capitalization of the first letter of the specific epithet, for example *Helichrysum Laneum* on p. 170, *Selago Zeyheri* on p. 226 and *Walafrida Geniculata* on p. 227.

In the Explanation of Scientific Name Authors, pp. 15–17, there are several spelling mistakes. For example, Wessels Marais should be Wessel Marais and Robert Allan Dyer should be Robert Allen Dyer. Sheila Hooper, presently cyperologist at Kew Herbarium, would be highly dismayed to learn that she has been written off as of the "19th Century".

This book contains much useful information to karoo farmers and the layman, but why put the book beyond the reach of such people by producing a de luxe work costing R25. The reasons for the high cost are obvious: the format is large (28,5× 25,5 cm), also the print size (16 point), high quality paper has been used and much space has been wasted throughout the book. The misleading title of the book will undoubtedly influence many people, who can afford it, into buying the book. A book on the lines of Karoo Plant Wealth would have been much more acceptable.

D. J. B. KILLICK

VEGETATION SÜDOSTEUROPAS. Geobotanica Selecta, Band IV. By I. HORVAT, V. GLAVAČ & H. ELLENBERG. *Stuttgart: Gustav Fischer Verlag.* 1974. Pp. xxxii+768, 412 figures, 153 tables, 2 vegetation maps. Price DM 360 (R90).

When Horvat, who was professor in botany at Zagreb University, Yugoslavia, died in 1963, he left a manuscript on the general ecological background of Southeastern Europe and piles of notes, tables and literature references which were to have formed

the basis for a description of the vegetation of that vast area. His student Glavač, who can read most of the many languages of Southeastern Europe in which papers on the vegetation were published, decided to continue the work of Horvat, and persuaded Ellenberg to help and take on the task of editing the final manuscript. It proved to be an immense task that took nearly eight years of hard work to complete. Glavač and Ellenberg always try to give interpretations with which they thought Horvat would have agreed. Otherwise, they give their own opinion and Horvat's opinion separately. Although the authors claim that the book has become a joint effort of all three, it is inevitable that the work bears the recognizable stamp of each author particularly Ellenberg.

The book treats the vegetation of Southeastern Europe, the Balkan peninsula south of 46° N latitude, against a background of geographical interrelationships. After a general part in which definitions and concepts are clarified and general ecological, climatological, pedological and phytogeographical information is provided, seven major vegetation zones or climax complexes, with the communities and the ecology of each major zone, are described in successive parts. These major zones are: (1) the evergreen mediterranean zone; (2) the deciduous sub-mediterranean mixed forest zone; (3) the zone of continental mixed forest and wooded steppes ("Waldsteppe"); (4) the central European lowland zone; (5) the montane beech forest zone; (6) the montane and subalpine coniferous zone; and (7) the alpine zone.

It is obvious that, despite the integration of data from a large number of scientific publications, published in many languages in a wide variety of journals and often difficult to obtain, a number of generalizations had to be made in the present book. Material from a few sites is sometimes described and presented as being generally representative for a wide area, probably mainly on the basis of climatological, topographical and phytogeographical data. But even with these drawbacks, this presentation of the variety of Southeastern European vegetation types and their ecological interpretation in one integrated and clear text is an enormous achievement for which the authors should be complimented.

The book contains many summarized phytosociological tables from which differences and similarities between related vegetation types are apparent. Photographs and diagrams richly illustrate the text and are instructive in showing the structure of plant communities and specific ecological features. The book has a reference list of about 1 500 publications, as well as a species index with author's names, an index of plant community names, an index of geographical names and a subject index. Two coloured vegetation maps show the vegetation zones of the entire area at scale 1:3 000 000, and the vegatation of the Northwest Yugoslavian Karst area at scale 1:500 000. A very brief summary in English explains some technicalities concerning tables and species, and of community, personal and geographical names used in the book.

For anyone concerned with the vegetation of Southeastern Europe the book will prove to be indispensable as a source of information on general ecology and as an example of what is possible in the field of integration and presentation of widespread local data. This book should be available in every botanical library.

M. J. A. Werger

Schwermetallvegetation der Erde. Geobotanica Selecta, Band V. By W. H. O. Ernst. *Stuttgart: Gustav Fischer Verlag.* 1974. Pp. X+194, 45 figures, 100 tables. DM 130 (R32).

This fifth volume in Fischer's series Geobotanica Selecta summarizes the present knowledge on the ecology of plant species and plant communities on heavy metal soils and describes the structure and floristic composition of the vegetation types on these sites. Professor Ernst, who has himself worked in Europe and in Africa on this subject, writes that so much specific knowledge on the biological consequences of heavy metals in soils has been gathered during the past twenty years, that it seems worthwhile to summarize it in a general form and draw causal conclusions. Besides, there is a need for a compilation of existing knowledge on this subject, since most of these plant communities are rapidly disappearing because of large-scale open pit mining.

In the first few chapters, Ernst compares figures of total percentages of heavy metals in the soil and the amounts that are available for plants, discusses the importance of microbial activity in those soils, and summarizes the autecological literature on plants known to occur specifically on those soils. Experiments have shown that heavy metal resistance is genetically controlled. Ernst points out that many species described from heavy metals sites can only be regarded as varieties and ecotypes of widespread species. He discusses some examples of "catastrophic selection" in some species, leading to a rapid development of heavy metal resistance in some populations. Resistant populations of some other species are rather ancient, however as must be concluded from their relic type of distribution area

After a description of succession on heavy metal soils in the Euro-West Siberian Region and of vegetation zonation on such sites in Europe and Africa, Ernst starts with the description of vegetation types, which covers more than half of the book. For description of the vegetation, Ernst follows the principles of the Braun-Blanquet method. This allows a ready comparison of the various vegetation types, but because it requires data sampled in an appropriate way, Ernst must largely restrict his descriptions to types occurring in Europe, Japan and Central Africa, where scientists have used this method. Very limited is the existing knowledge on species composition and structure of vegetation types on heavy metals soils in North America, continental Asia, Australia, Polynesia and South America. Ernst gives concise descriptions of the communities and provides notes on their ecology and distribution area. Many phytosociological tables are given, showing species composition and facilitating comparison. Photographs, maps and tables illustrate the descriptions.

Indices of species, including author's names, and of geographical localities quoting latitude and longitude, increase the reference value of this book.

This book presents a valuable and fairly complete inventory of the literature on vegetation of heavy metal soils; it summarizes the data and draws conclusions, but at the same time stimulates further research by clearly pointing out the gaps in our knowledge of this subject.

M. J. A. Werger

Flore et Végétation de Madagascar. Flora et vegetatio mundi, Band 5. By J. Koechlin, J.-L. Guillaumet & Ph. Morat. *Lehre: J. Cramer Verlag & Vaduz: A. R. Gantner Verlag Commanditgesellschaft.* 1974. Pp. xiv+688, 29 figures, 23 maps, 188 photographs. DM 250 (R60).

The extraordinary and most interesting flora and vegetation of the large island Madagascar, about 500 km off the coast of Moçambique, has been well-described in the present book. Madagascar became disconnected from the remnants of Gondwanaland about a hundred million years ago and has since been isolated. This has resulted in an unusually high degree of endemism in the flora (about 400 genera are endemic) and fauna. Apart from this high degree of endemism, the flora is also extremely rich, amounting to about 12 000 species of which only a small number is not indigenous. Owing to its latitudinal situation in the Indian Ocean and to its varied topography (the highest point reaching 2876 m), Madagascar is characterized by strongly contrasting environments, which bring about a great diversity in vegetation types. Some of these vegetation types, like the baobab forests and the thorny shrub formations dominated by Didiereaceae, are structurally unique in the world. This unique piece of nature is, however, severely threatened by overexploitation. In Madagascar the vegetation is continuously damaged by too frequent fires and by a cattle population that is twice as large as the already considerable human population. To all these aspects of the environment the authors pay appropriate attention in the first part (four chapters) of their book.

The second part presents in eleven chapters a detailed account of flora and vegetation. It starts with a chapter on the botanical exploration and classical phytogeographical subdivision of Madagascar, discussing mainly the important works of H. Perrier de la Bathie and H. Humbert concerning the phytogeography of Madagascar. The vegetation is described on a structural basis, paying much attention to the physiognomy of vegetation formations as proposed in the Yangambi system and to growth forms and organs of the taxa (grouped according to families) encountered in these formations. Ten chapters successively describe in detail the evergreen forest of lower altitudes and the coastal forest, the dry forests of western Madagascar, the sclerophyllous forest of middle high altitudes, the xerophilous vegetation of south-western Madagascar, the montane forests, the degradation stages of forest vegetation, the graminoid formations, the xerophilous rupicolous vegetation, the swamp and fresh water vegetation, and the halophilous vegetation. Particularly the montane forests, grasslands, and rupicolous vegetation appear to have a considerable floristic affinity with corresponding vegetation types in South Africa, but the rupicolous Madagascan vegetation especially, is very much richer in peculiarly formed species. The text is illustrated with instructive drawings and structural profiles, as well as with photographs of the various vegetation types. It is a pity that, in a book of this standing, the photographs generally are of such poor quality. They do not always show the characteristics of the vegetation, are grey and without contrast, and some even appear to be not entirely in focus. Maps show the distribution of the various formations over the island.

The third part of the book gives a résumé of the general characters of the vegetation and flora of Madagascar. The authors return to the theme of the degradation of the vegetation

on Madagascar and put forward the question of why the original Malagasian ecosystems are so fragile. They conclude that a changing climate and unfavourable pedological conditions are important factors causing the fragility of the original ecosystems, which through the action of man have been rapidly destroyed. The last chapter also contains a quantitative phytogeographical analysis of the flora of Madagascar, and a brief essay on speciation in Madagascar which, in some genera, is extraordinarily large. The authors point out the favourable past and present conditions of Madagascar allowing such an abundant speciation, and conclude that Madagascar certainly must be one of the most favourable places to study evolution in the plant kingdom. A species index citing author's names is added to the text.

This work is an invaluable addition to our understanding of this interesting, but generally little-known paradise of plant life.

M. J. A. Werger

The Flora of Swaziland by R. H. Compton. *Kirstenbosch: Trustees of the National Botanic Gardens of South Africa.* Supplementary Volume No. 11 to Journal of South African Botany. 1976. Pp. 684. Price R15.

On a subcontinent with a flora as rich as that of southern Africa regional floras are an invaluable tool to the field botanist. Such works, however, are still very scarce in this part of the world. Professor Compton's *magnum opus*, which was published on the 6th of August 1976, his 90th birthday, is therefore most welcome.

The work describes about 2 118 indigenous species of flowering plants which are included in 134 families and 783 genera. Families and genera are arranged, numbered and also largely circumscribed according to Phillips's Genera of South African Flowering Plants (1951). Species are presented in alphabetical sequence in their genus. A key to families is unfortunately not provided, but the key in Dyer's Genera of Southern African Flowering Plants (1975, 1976) can obviously be used. Parallel keys, printed in 8 pt, are provided to genera and species. They are largely artificial and make use of simple characters, and few contrasts occupy more than a single line. No reasons are given why parallel keys were decided on in preference to indented ones which at a glance convey some insight into the grouping of the taxa being dealt with. The additional space which indented keys would have occupied could most probably have been made up by omitting the heading given to every single key and by setting the left margin of the species keys less far in. Occasionally the reader has to choose between more than two contrasts. This is taken to the extreme in the key to the species of *Crassula* on p. 221 which is difficult to comprehend. The saving of a few lines thus effected seems hardly justified. In the keys to genera no reference or page number is assigned to the names of genera to help the reader find the treatment of the genus in the text. This is a disadvantage especially in the larger families.

As the author points out, the descriptions of families and of genera, as well as the keys, are often partly based on those in Phillips's Genera and in the Manual of Flowering Plants and Ferns of the Transvaal with Swaziland by Burtt Davy (1926, 1932). Species descriptions are newly drawn up with reference to plants collected in Swaziland. Technical terms "with which systematic botany is overburdened" have been avoided as far as possible and descriptions are short and image-creating. This is of great importance in a flora containing no illustrations. The average species description is no longer than 50–60 words and genus descriptions seldom exceed 100. The lack of a glossary will probably not be noticed by anyone with some botanical training especially as unavoidable "technicalities" in families such as grasses and composites are explained in the family descriptions.

Notes on the region, the habitat, flowering times and voucher specimens with collecting localities are given for every species. In some instances as many as 15 vouchers are cited. The reason for this is not obvious especially as localities are not identified in terms of districts, regions or the degree reference system. An alphabetical list of all localities quoted in the text is provided, but unfortunately only the altitude in metres is indicated. It is thus difficult to form a clear picture of the distribution of a species within the country. No reference is made to the occurrence outside Swaziland.

No synonyms are cited either in the text or in the index, but a list of recently changed names, not taken up in the text, is given as an appendix. An asterisk has been placed in the text against each species for which an alternative name is provided in this appendix. The meaning of the asterisk remained obscure to the reviewer until he found the explanation in the appendix on p. 675. No reference is made to literature or the economic value of species and abundance is only occasionally mentioned.

Common English names are given for some families and si-Swati names are mentioned for numerous species. No index to common names is provided.

Prof. Compton began his botanical survey of Swaziland during 1955 Eleven years later he published his Annotated Check-list of the Flora of Swaziland as supplementary Volume No. 6 of the Journal of South African Botany. During the same year he began to compile the present flora, which is largely based on the material he collected for his check list. The author mentions that he did not think it necessary to repeat most of the specialized information in the flora. In the reviewer's opinion it would have been justified to repeat at least the map of the area and the alphabetical lists of common plant names and to give a short resumé of the notes on the vegetation of Swaziland. The work ends with an index listing only current names of families and genera. Much attention was apparently given to proof-reading, but more care could have been taken with abbreviations of author names. This is particularly evident on pp. 460 and 675. The title of the work, repeated in the top margin of every page, could rather have been replaced by the name of the family being dealt with on the page in question.

The Flora of Swaziland is neatly printed and well-bound, true to the tradition of the Journal of South African Botany. The work is warmly recommended to all serious students of the flora of Swaziland and of regions beyond its borders. At a price of R15 this is the "Botanists' Bargain of the Year". We wish to congratulate Professor Compton on setting up this milestone along the long road to a fuller understanding of the southern African flora.

O. A. Leistner

A Generic Monograph of the Meliaceae by T. D. Pennington & B. T. Styles. *Blumea* 22: 419–540 (1975).

In their introduction the authors state that, for its size, the family Meliaceae probably contains a wider range of floral and fruit structures than any comparable group. Further, that the family is among the more useful to man for its high quality timbers. There have, however, been persistent disagreements for the past 200 years as to the number of families and genera to be included in Meliaceae. These are very good reasons for undertaking a thorough generic monograph of the family.

The project is divided into two main sections, the first being a critical evaluation of earlier work and a sharp focus on aspects of general morphology, wood structure and pollen. The conclusions to be drawn from the results are clearly summarized.

The second part is a conspectus of the family as a whole, where the circumscription of the family and the 51 genera accepted for it is given in detail, accompanied by full references to literature and synonymy. The differential floral structures of the genera are illustrated by clear diagramatic line drawings, which are of a consistently high standard.

As far as the monograph concerns the genera present in southern Africa, the two most controversial being *Nymania* and *Ptaeroxylon*, the authors state that their results show convincingly that the former is Meliaceous and that the latter must be excluded.

In the Genera of Southern African Flowering Plants 1: 296–299 (1975), before the present work was available, I followed Harvey and Sonder in Flora Capensis 1: 242–243 (1860) by giving both genera family rank, the "un-Meliaceous-like looking" *Nymania* in Aitoniaceae and *Ptaeroxylon* in Ptaeroxylaceae.

Now the authors of the monograph show that the character of the pollen grains of *Nymania* and the structure of the secondary xylem place it clearly in Meliaceae, with *Turraea*, also present in southern Africa, a close relative. *Nymania* will consequently be "reassigned" to Meliaceae in the Flora of Southern Africa.

As for *Ptaeroxylon*, it was confirmed that it has a strong affinity with *Cedrelopsis* in its pollen morphology, unlike that of any accepted Meliaceae. Although there is apparently some affinity with Sapindaceae and Rutaceae, the most satisfactory solution is to give the two genera family rank as Ptaeroxylaceae. In this decision I am pleased to agree, having been guided by the treatment of the family by White & Styles in Flora Zambesiaca 2: 547 (1966).

The authors' treatment of *Nymania* and *Ptaeroxylon* gives one a feeling of confidence in the monograph as a whole.

R. A. Dyer

GUIDE FOR AUTHORS

GENERAL

Bothalia is a medium for the publication of botanical papers dealing with the flora and vegetation of Southern Africa. Papers submitted for publication in Bothalia should conform to the general style and layout of recent issues of the journal (from Vol. 11 onwards) and may be written in either English or Afrikaans.

TEXT

Manuscripts should be typed, double-spaced on one side of uniformly-sized A4 paper having at least a margin of 3 cm all round. Latin names of plants should be underlined to indicate italics. All other marking of the copy should be left to the editor. Metric units are to be used throughout. Manuscripts should be submitted in duplicate to the Editor, Bothalia, Private Bag X101, Pretoria.

ABSTRACT

A short abstract of 100–200 words preferably in both English and Afrikaans should be provided. In the abstract the names of new species and new combinations should not be underlined.

FIGURES

Black and white drawings, including graphs, should be in jet-black Indian ink preferably on bristol board. Lines should be bold enough to stand reduction. Indicate the desired lettering lightly in pencil: the printer will insert the final lettering. If authors prefer to do their own lettering, then use some printing device such as stencilling, letraset, etc. It is recommended that drawings should be twice the size of the final reduction.

Photographs submitted should be of good quality, glossy, sharp and of moderate, but not excessive contrast. Photograph mosaics should be composed by the authors themselves: the component photographs should be mounted neatly on a white card base leaving a narrow gap between each print; number the prints using some printing device.

Figures should be planned to fit, after reduction, into a width of 8 cm, 11 cm or 17 cm with a maximum vertical length of 24 cm.

The number of each figure and the author's name should be written on the back of the figure using a soft pencil.

Captions for figures should be collected together and typed on a separate page headed *Captions for Figures*. A copy of each caption should be attached to the base of each figure. Do not underline plant names in captions—only collectors' names and numbers.

Authors should indicate in pencil in the text where they would like their illustrations to appear.

TABLES

Tables should be set out on separate sheets and numbered in Arabic numerals.

CITATION OF SPECIMENS

In citing specimens the grid reference system should be used (Technical Note: Gen. 4,4c). Provinces/countries shoud be cited in the following order: S.W. Africa, Botswana, Transvaal, Orange Free State, Swaziland, Natal, Lesotho and the Cape. Grid references should be cited in numerical sequence. Locality records for specimens should preferably be given to within a quarter-degree square. Records from the same one-degree square are given in alphabetical order i.e. (–AC) precedes (–AD), etc. Records from the same quarter-degree square are arranged alphabetically according to the collectors' names; the quarter degree references must be repeated for each specimen cited. The following example will explain the procedure:

Natal.—2731 (Louwsburg): 16 km E. of Nongoma (–DD), *Pelser 354*; near Dwarsrand, *Van der Merwe 4789*, 2829 (Harrismith): near Groothoek (–AB), *Smith 234*; Koffiefontein (–AB), *Taylor 720*; Cathedral Peak Forest Station (–CC), *Marriott 74*; Wilgerfontein, *Roux 426*, Grid ref. unknown Sterkstroom, *Strydom 12*.

Records from outside Southern Africa should be cited from north to south i.e. preceding those from Southern Africa, The abbreviation "distr." should be added to all district names, e.g.

Kenya.—Nairobi distr.: Nairobi plains beyond race course, *Napier 485*

GIDS VIR SKRYWERS

ALGEMEEN

Bothalia is 'n medium vir die publikasie van plantkundige artikels wat handel oor die flora van Suidelike Afrika. Artikels wat voorgelê word vir publikasie in Bothalia behoort ooreen te stem met die algemene styl en rangskikking van onlangse uitgawes van die tydskrif (vanaf Vol. 11). Dit mag in Engels of in Afrikaans geskryf word.

TEKS

Manuskripte moet getik wees in dubbelspasiëring slegs op een kant van ewegroot A4 papier, met reg rondom 'n rand van minstens 3 cm breed. Latynse name van plante moet onderstreep word om aan te dui dat dit kursief gedruk moet word. Alle ander merke moet aan die redakteur oorgelaat word. Metrieke eenhede moet deurgaans gebruik word. Manuskripte moet in tweevoud ingedien word by die Redakteur, Bothalia, Privaatsak X101, Pretoria.

UITTREKSEL

'n Kort uittreksel van 100–200 woorde moet voorsien word, verkieslik beide in Engels en Afrikaans. In die uittreksel moet die name van nuwe soorte en nuwe kombinasies nie onderstreep word nie.

AFBEELDINGS

Wit en swart tekeninge, insluitende grafieke, moet met pikswart Indiese ink geteken word, verkieslik op "bristol board". Lyne moet dik genoeg wees om verklein te kan word. Dui die verlangde byskrifte liggies in potlood aan: die drukker sal die uiteindelike byskrifte invoeg. Indien skrywers verkies om hulle eie byskrifte te maak, gebruik dan een of ander hulpmiddels soos letraset of 'n sjabloon. Dit is wenslik dat tekeninge tweemaal so groot as die uiteindelike verkleining sal wees.

Fotos wat ingedien word, moet van hoë kwaliteit wees—glansend, skerp en van matige maar nie oordrewe kontras. Fotomosaïeke moet deur die skrywer self saamgestel word: die afsonderlike fotos moet netjies monteer word op 'n stuk wit karton met 'n smal strokie tussen die fotos; nommer die fotos met behulp van een of ander druk-hulpmiddel.

Afbeeldings moet so beplan word dat hulle na verkleining sal pas in 'n breedte van 8 cm, 11 cm of 17 cm met 'n maksimum vertikale lengte van 24 cm.

Die nommer van elke afbeelding sowel as die skrywer se naam moet op die rugkant van die afbeelding geskryf word met 'n sagte potlood.

Onderskrifte vir afbeeldings moet bymekaar getik word op 'n afsonderlike bladsy met die opskrif *Onderskrifte vir Afbeeldings*. 'n Afskrif van elke onderskrif moet aan die onderkant van elke afbeelding vasgeheg word. Moenie plantname in onderskrifte onderstreep nie, slegs versamelaarsname en -nommers.

Skrywers moet met potlood in die teks aandui waar hulle graag hulle afbeeldings wil hê.

TABELLE

Tabelle moet op afsonderlike velle papier kom en genommer word met Arabiese nommers.

SITERING VAN EKSEMPLARE

Wanneer eksemplare siteer word, moet die ruitverwysingstelsel gebruik word (Tegniese Nota: Gen. 4, 4c). Provinsies/lande moet in die volgende volgorde siteer word: Suidwes-Afrika. Botswana, Transvaal, Oranje-Vrystaat, Swaziland, Natal, Lesotho en die Kaapprovinsie. Ruitverwysings moet in numeriese volgorde siteer word. Lokaliteitsrekords vir eksemplare moet verkieslik tot binne kwartgraadvierkante gegee word. Rekords uit dieselfde eengraadvierkant word in alfabetiese volgorde aangebied, nl. (–AC) kom voor (–AD) ens. Rekords uit dieselfde kwartgraadvierkant word alfabeties gerangskik volgens die versamelaars se name, en die kwart graadverwysings moet herhaal word vir elke eksemplaar wat siteer word. Die volgende voorbeeld sal die metode verduidelik:

Natal.—2731 (Louwsburg): 16 km O. van Nongoma (–DD), *Pelser* 354; naby Dwarsrand, *Van der Merwe 4789*, 2829 (Harrismith): naby Groothoek (–AB), *Smith 234*; Koffiefontein (–AB), *Taylor 720*; Cathedral Peak Bosboustasie (–CC), *Marriott 74*; Wilgerfontein, *Roux 426*; Ruitverwysing onbekend: Sterkstroom, *Strydom 12*.

Rekords van buite Suidelike Afrika moet siteer word van noord na suid, d.w.s. dit gaan dié van Suidelike Afrika vooraf. Die afkorting "distr." behoort by alle distriksname gevoeg te word, bv.

Kenya.—Nairobi-distr.: Nairobivlakte anderkant die renbaan, *Napier 845*.

REFERENCES

References in the text should be cited as follows: "Jones (1955) stated . . ." or ". . . (Smith, 1956)" when giving a reference simply as authority for a statement. The list of references at the end of the article should be arranged alphabetically and the literature abbreviations used should conform to the list of Literature Abbreviations (Technical Note: Tax. 6/1) issued by the Botanical Research Institute, thus:

Hutchinson, J., 1946. *A botanist in Southern Africa.* London: Gawthorn.

Morris, J. W., 1969. An ordination of the vegetation of Ntshongweni, Natal. *Bothalia* 10: 89–120.

If, as in many taxonomic papers, periodicals or books are mentioned in the text, usually in the species synopsis, they should be cited as in the following examples: Gilg & Ben. in Bot. Jahrb. 53: 240 (1915) and Burtt Davy, Fl. Transv. 1: 122 (1926).

REPRINTS

Authors receive 75 reprints gratis. If there is more than one author, this number will have to be shared between or among them.

VERWYSINGS

Verwysings in die teks moet as volg siteer word: "Jones (1955) beweer . . ." of ". . . (Smith, 1956)" wanneer 'n verwysing slegs as outoriteit vir 'n stelling gegee word. Die verwysingslys aan die einde van die artikel moet alfabeties gerangskik wees en die literatuurafkortings wat gebruik word, moet in ooreenstemming wees met die lys van Literatuurafkortings (Tegniese Nota: Tax. 6/1) wat uitgegee is deur die Navorsingsinstituut vir Plantkunde, as volg:

Hutchinson, J., 1946. *A botanist in Southern Africa.* London: Gawthorn.

Morris, J. W., 1969. An ordination of the vegetation of Ntshongweni, Natal. *Bothalia* 10: 89–120.

Wanneer, soos in baie taksonomiese artikels die geval is, tydskrifte of boeke in die teks genoem word, gewoonlik in die soortsinopsis, behoort hulle siteer te word soos in die volgende voorbeelde: Gilg & Ben. in Bot. Jahrb. 53: 240 (1915) en Burtt Davy, Fl. Transv. 1: 122 (1926).

HERDRUKKE

Skrywers ontvang 75 herdrukke gratis. Wanneer daar meer as een skrywer is, sal hierdie aantal tussen hulle verdeel moet word.

PUBLIKASIES VAN DIE NAVORSINGSINSTITUUT VIR PLANTKUNDE

Beskikbaar van die Afdeling Landbou-inligting. Departement van Landbou-tegniese Dienste, Privaatsak X144, Pretoria, Republiek van Suid-Afrika.

FLORA VAN SUIDELIKE AFRIKA

'n Taksonomiese behandeling van die flora van die Republiek van Suid-Afrika, Lesotho, Swaziland en Suidwes-Afrika.

Aanvanklik in volumes, maar in die toekoms as dele.

Reeds beskikbaar:

Vol. 1 (1966) Prys R1,75. Oorsee: R2,20. Posvry.

Vol. 13 (1970) Prys R10. Oorsee: R12. Posvry.

Vol. 16,1 (1975) Prys R13,50. Oorsee: R16,75. Pos vry.

Vol. 26 (1963). Prys R4,60. Oorsee: R5,75. Posvry.

DIE BLOMPLANTE VAN AFRIKA

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